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## ENAMELED SANITARY WARE MANUFACTURE*


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THE making of porcelain enameled sanitary ware, or hollow ware, has long been an important industry in the United States, increasing in importance each year. There are few dwellings built in these days which are not equipped with a porcelain enameled bathtub and a kitchen sink. It is one of the lead trades, for the majority of factories still use a lead enamel and the character of the work is such that exposure to lead dust is almost inevitable and is likely to be excessive unless great precautions are taken. Some seventeen years ago, in 1911 to 1912, in the course of a series of studies of the lead trades for the United States Bureau of Labor Statistics, I visited the principal hollow ware factories and searched out the cases of lead poisoning which had occurred during the preceding two years among the men employed in making and applying enamel. Another dangerous occupation, the use of the sand blast to prepare the ware for enameling, did not come within my province and was not included in the investigation.

Sixteen years later, in 1927 to 1928, I made a second survey of this industry and found that the situation had changed very much in some important features, enough so to warrant a second report. This later study was not so intensive as the earlier, inasmuch as no effort was made to search out cases of lead poisoning, as had been necessary in 1911. New methods of management and changes in technic made that part of the investigation superfluous. On the other hand, the later study did include the departments where men are exposed to silica dust in cleaning ware for enameling.

### SANITARY WARE MANUFACTURE IN 1911 TO 1912

#### *Mixing Enamel and Enameling*

The study of 1911 to 1912 covered ten factories, the five largest in the country, two medium-sized, and three


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smaller ones, employing some 900 enamelers and 112 millmen. Conditions in one of these were surprisingly good, but the others were for the most part operated without precautions and conditions existed which were fraught with much danger to the health of the men employed. No plant had a physician in charge, in none was physical examination a prerequisite for employment, and such a thing as a routine examination of lead workers had never been thought of. Labor was abundant and cheap and a high turnover so usual that it was not considered poor practice but inevitable. Indeed, in some plants the foremen of the mills preferred to keep the mixers of enamel only a short time because they wished to avoid the serious lead poisoning which followed a long exposure.

The work of enameling sanitary ware consists in preparing the enamel and applying it. The former is done in the mill which is quite separate from the enameling rooms. In 1911 these mills were crude in equipment or in management or in both; the lead oxides and other ingredients were kept in open bins and usually were simply shoveled out on the floor and mixed together with a hoe, or shoveled into a closed mixer from which the mix was dumped into a truck or dropped through an unprotected chute in the floor. In only two was there an attempt to prevent dangerous dust by placing a hood with an exhaust over the lead oxide bin. The raw ingredients are fused in a furnace, the hot liquid mass is run out into a tank of water where it "frits," and the frit is ground to fine powder in a mill. At that time all this work was carelessly done, mixing machines and mills leaked, contaminating the air, and dust was allowed to accumulate in heaps on the floor.

The ironware that is to be enameled, the bathtub or sink, is prepared for coating by rigorous cleansing with a sand blast and then by the so-called slush coat, which is practically lead free and which at that time was applied to the surface with a paintbrush. After this has dried, the ware goes to the enameler and his helper who place it in a furnace till it is red hot, bring it out to a turntable, and scatter enamel rapidly over it from a dredge mechanically shaken, handled by the enameler while his helper manages the turntable; then they return it to the furnace where the enamel melts and flows smoothly over the surface. This process is repeated several times, the number of coats depending on the grade of the ware.

In 1911 this was heavy, hot, and dusty work. The men were in a thick fog of lead enamel dust most of the time. While the ware was in the furnace there was a brief interval, longer for large ware than for small, when they could pause and go over to the window or out of doors for a breath of air and coolness, but even this was not possible when they worked on double furnaces, turning from one to the other without stopping. There was no pause for lunch, the men ate in the intervals of work, with unwashed hands, laying down the food anywhere to run back to the furnace, then picking it up again. Several times the wife of an enameler told me of finding white powder in her husband's lunch box.

In 1911 the upkeep in the enameling rooms was often fairly good, for if too

much dust is allowed to accumulate it drifts down from ceiling, walls, and other surfaces and mars the freshly made coating. Therefore, every two to four weeks there was a housecleaning, on Sunday, and compressed air was used to blow down the dust. This was excessively dusty work, done usually by an enameler's helper. But the dust inherent in the work was not controlled in any effective way, the physical effort in handling the large ware was great, and the workday was usually eight hours long, without a break. As for the presence of lead in the enamel, that was admitted by all employers and industrial chemists but the statement was usually qualified by the assertion that the fusing of the lead oxide with the silicious compounds to make enamel resulted in changing all the lead oxide to an insoluble and therefore nonpoisonous silicate. We consulted A. V. Bleininger, then of the United States Bureau of Standards, as to this and were assured by him that it was impossible "for the simple reason that there is not enough silica to go round." Tests of enamels actually in use were made for us by the United States Bureau of Chemistry for the purpose of determining, not how much lead was present in each, but how much lead was present in a form to be readily dissolved in human gastric juice. This is the so-called Thorpe test which is used commonly by the British Factory Inspection Service to determine the degree of danger in handling different lead mixtures; and it consists in subjecting the mixture to digestion for two hours in 0.25 per cent. hydrochloric acid, then estimating the lead which has passed into solution. The seven enamels showed proportions of soluble lead running from 0.51 to 20.4 per cent. At that time it was customary to use more lead in the enamel on curves and edges than for flat surfaces.

A search for lead poisoning among the men was a difficult task, in the absence of any medical service in the plants, but it was possible to discover in hospital records and from interviews of physicians and examination of men then employed 217 cases which had occurred during 1911 to 1912 in a force supposed to number 1,012 men. Given the great labor turnover, this last figure is far from covering the number of men exposed during the year, but neither does 217 cover all the cases. The most nearly accurate estimate was obtained by the examination of 148 strikers, in two towns, 36 per cent. of whom showed unmistakable signs of plumbism. The character of the disease was severe in many cases (naturally, for those reported to us were hospital cases and cases striking enough to have left an impression on the memory of physicians). There were twenty-eight cases of palsy, eight of encephalopathy, and seven deaths. The development of an intoxication was often rapid, in forty-five out of ninety-four cases the period of exposure before an attack was less than a year. Another indication of the unhealthfulness of the occupation was to be seen in the fact that, although it is a skilled and relatively well-paid job, the average trade life of 250 men was only six years.

To sum up, the unhealthful features of the enameling of sanitary cast-iron ware in 1911 were the following:

1. The use of a glaze rich in soluble lead (Thorpe test).

2. Excessive dust in almost all enamel mills.

3. Excessive dust in enameling.

4. Great heat and physical exertion in enameling.

5. No pause for lunch; lunch eaten in enameling room while work went on.

6. Washing facilities absent or inadequate.

7. No medical service in the plants.

8. A large turnover and no instruction of newly employed men in measures for the prevention of plumbism.

These combined to make an unusually dangerous lead trade with a high incidence of plumbism, which was frequently severe in type and developed after a short exposure.

## Sanitary Ware Manufacture in 1927 to 1928

### *Mixing Enamel and Enameling*

As in 1911 to 1912, ten plants were studied, the six largest in the country, three medium-sized, and one small plant. The men employed in enameling in these plants number, roughly (for it varies according to season), 1,430; those engaged in preparing enamel, 180, making about 1,600 exposed to the effect of enamel, raw or fritted.

The first important change noted was the lessening of the amount of lead used. This is true in all but the smallest plant, where the low heat in the furnaces makes a mixture rich in lead desirable. Of the other nine, three use no lead, or only a trace (0.5 per cent.), or use lead only in the "acid resistant" enamel put on kitchen sinks. Six still use lead but less than before. For instance, the chemist of a plant employing over 150 enamelers said: "We use about 120 parts of red lead to 2,000 parts of enamel, or 6 per cent., but we no longer use a higher percentage for the enamel on curves as we did. Acid proof enamel has slightly less lead." Another, employing 333 enamelers, uses about 4 to 5 per cent. of litharge, for all but acid proof enamel, the formula for which is secret but calls for lead. In a third it was stated that, while in 1912 the red lead in the enamel ran up to 20 per cent., now it is hardly 10 per cent.

According to Homer F. Staley, formerly of the United States Bureau of Standards, an expert in the field of ceramics, there is far less lead used now than in 1911, even in lead enamel, while the use of enamels free from lead is increasing and bids fair to become universal. A typical formula in 1911 called for a low boric oxide content, tin oxide as an opacifier, and 21 per cent. of lead oxide. Since then, sodium antimonate has supplanted tin oxide as the opacifier and along with this change has gone a progressive elimination of lead oxide, which is undesirable if a uniform color is to be maintained. "The great advantage of leadless enamel is that one can get pure white and creamy white surfaces of absolute uniformity when sodium antimonate is used as the opacifier, but anything over 14 per cent. of lead oxide in these enamels injures the color and indeed the latter is never as clear and beautiful as it is in lead free enamel. The hold of lead enamel on industry is based on the early experience with leadless mixtures by men who did not understand their proper compounding." Mr. Staley believes that fully one-quarter of the enamel ware manufacturers now use no lead and the rest use somewhere between 6 and 10 per cent., with 15 per cent. as the maximum.

The second change noted in 1927 was the lessening of dust. Conditions in the milling departments have improved very decidedly during the last sixteen years and there is now not only less lead used in the mix but far less escape of dust in handling it. Four of the large plants have had all the bins placed under a long hood with an exhaust at the back of each bin. The car for the mix runs on a rail in front of the bins and the men are trained to lift out all the compounds with care and drop them into the car without producing dust. These men wear respirators while doing the work of compound weighing. In all except the smallest plant there is very careful handling and the use of respirators is general. Still, in the most modern mixing room, there is one bad spot, the dump that leads down to the mixing machine. Here the weighed ingredients, containing in most places unchanged lead oxide, are dropped from the car through a simple hole in the floor without even a hood above it. It is probably here that one finds the explanation for the fact that most mixing rooms have more or less dust in the corners and along the edges of the wall, dust showing the presence of red lead or litharge. In more than one instance the accumulation of dust is really shocking. It would seem to be a simple matter to enclose this dump and provide a mechanism to tip up the truck, controllable by a lever on the outside. In one of the medium-sized plants such a device may be seen, working neatly and efficiently.

Another source of lead dust in some of the compound rooms is the opening and emptying of kegs or barrels of oxide, always a dusty process and one usually done without any precaution, although not always in that room. The kegs may be opened on the floor above and the contents run down to the bins below. One large plant has an excellent arrangement which deserves to be copied. The oxide barrels are opened on the shipping platform, out in the open air, and there emptied into a screw conveyor which carries the lead to bins in the mixing room, a carload at one time.

From compound room to mixing machine, from there to the smelting furnace, the fritting tanks, and the enamel mill, there is no handling and, in a well-constructed plant, no leaking of dust. Unfortunately, mixing machines frequently do leak and so do grinding mills. All but three mills are still far more dusty than they should be, heaps of dust collect, and the floors are rough and hard to clean, especially as the dust is valuable and therefore wet cleaning cannot be used because water would dissolve out some of the constituents.

The enameling of sanitary ware has also improved during these years; there is rather less dust everywhere, the dust has less lead and may have none, and the need for excessive physical effort is decidedly lessened by improvements in mechanical devices for handling the heavy ware. In modern plants the furnace door is drawn up by compressed air or electricity, the ware is lifted from the turntable to the furnace and back again with little effort on the part of the men, and the turntable is controlled by a foot lever, while the weight of the dredge is taken by a chain from the ceiling. Heat is as great an evil as ever in many plants, though, in others, hanging screens of

iron offer some protection, and well-constructed, properly placed hoods help to carry it off; poorly placed hoods only aggravate the trouble. An ordinary electric fan adds much to the comfort of the enameler and might be provided in every plant. Summer is always the heaviest season in this trade and nobody denies that the enameler's work is excessively trying in hot weather. The glowing ware is fiercely hot. I found that 12 feet was as near as I cared to approach a tub just out of the furnace, but most enamelers work standing only 4 feet away. Some use a face screen of wood or an aluminium or tin pie pan, with eyeholes and a stick fastened at right angles to catch between the teeth. The most comfortable arrangement is a light tin plate fastened to a tin hoop which fits around the head.

It is still true that the enameler is expected to work his shift, eight hours or six hours, without pause for lunch. The furnaces are going and must be used. Three shifts are the rule for single furnaces, but if a man is on two furnaces he works only six hours, for there is practically no respite during work, as he turns from one furnace to the other without stopping. In some plants six hours is the usual shift; in others it is resorted to in summer when the men cannot be pushed too hard. The uninterrupted workday means that the man must go lunchless or snatch his food during the few minutes when the newly enameled ware is in the furnace. I saw this several times, the lunch boxes near at hand, the men taking out sandwiches in their unwashed hands, laying them down anywhere when they went back to the furnace, the box left open to collect dust as the enameling went on. Such practice is forbidden by law in Great Britain in any workplace where lead is present.

Dry sweeping is still the accepted way of cleaning the floor, and blowing with compressed air is still the method used for getting rid of the dust from walls, hoods, and ceiling. Yet there is certainly less dust than in the old days, and four plants, three large and one medium-sized, have beautifully clean enameling rooms. The best one has six long shops in a row and the visitor can look down the whole length while work is going on and see no visible dust in the air. Here, over each furnace is a hood with a strong exhaust and much enamel dust is recovered from it. There is a fan in the wall opposite each enameler, well up toward the roof, to drive in fresh air, and an ordinary electric fan for coolness is placed close to where he stands at work. One smaller plant also has efficient hoods over each enameling place, the edge coming down to within 4 feet of the top of the ware.

A word should be said about the slush coat or ground coat, the liquid which goes on the cleaned ware just before it is enameled. Formerly this was applied with a paintbrush and, even when lead was present in the mixture, the work was practically harmless because there was no dust. Now the coat is sprayed on, except in one plant where they pour it. The pressure in the spray gun varies very much, from 35 pounds to almost 100 pounds, and of course the higher the pressure, the greater the formation and scattering of mist. There is little if any lead in it, but there is, according to the statement of H. F. Staley and

of several company chemists, more or less free silica. Since hoods are rarely provided and none is entirely efficient, this job is one that should be classed among the unhealthful ones, although the risk of lead is far below that in mixing and enameling, and the risk of silica far below that in sandblasting.

The health and welfare of the men is now a subject of real concern in all these plants, even in those states which have no compensation for occupational disease. It was interesting in one of these latter to contrast the attitude of sixteen years ago with that at present. Formerly men came and went, with nobody knowing or caring why and with nobody feeling any responsibility for their sickness or health. Now there is a manager who himself looks over the absentee cards each morning and follows them up, and who prides himself on a yearly labor turnover of only 2 to 4 per cent. He has instituted a routine medical examination of enamelers and millmen, and a similar system is already in force in three other plants, fortunately the largest in the country. A fifth is about to install a physician, but the others, including one large plant, have only emergency medical care.

It is evident that these changes must have lessened very much the incidence of lead poisoning in the industry and all the available data point to this conclusion. Three of the plants are situated in states which require the reporting of industrial plumbism and inquiry reveals no reported cases during the last two years. With regard to the other plants, one uses no lead, and the testimony of physicians in connection with the others goes to show that lead poisoning is not nearly so common as it was in former years. Thus in one plant which employs 125 enamelers and twenty-two millmen there has been no serious case in four years. If a man begins to lose weight, he is examined, and if he proves to have plumbism, he is shifted to other work. In another, with 335 enamelers and fifty millmen, which uses a glaze containing from 4 to 5 per cent. of litharge, the dispensary records show from four to six cases a month, but none of them serious, for the cases are detected now at an early stage. Shifting susceptible men to lead free work is a common practice now.

In spite of the improvements which have taken place in this industry, it is a significant fact that the working life of the enameler is still short, although his wages are good and his hours often less than the average. One large plant points with pride to a veteran who has worked at the trade for twenty-two years; another has one with eighteen years of service. Since the men start in at 18 or 20 years of age, it is plain that the great majority must give it up before they reach the age of 40 years.

### *Ware Cleaning Sandblasting*

The study of 1911 to 1912 covered only the lead hazard in this industry, not the hazard of silicosis which at the present time is certainly far more serious than the former and probably always was. In discussing with physicians lead poisoning in the industry sixteen years ago, I was often told that I ought to turn my attention to the sand blasters whose work was much more unhealthful than that of millmen and enamelers. One foreman of many years' experience told me that

he had never known a sand blaster to last more than four years. In this second study I have included the work of sand blasters and their helpers, and of the cleaners and grinders of cast-iron ware as it comes from the foundry. These men, all exposed in greater or less extent to dust rich in free silica, number about 1,065 in the ten plants under consideration.

It was not possible for me to have estimations made of the actual dust content of the air in the sand blast chambers but even if it had been, there would have been no need, for the conditions are the same as those studied by Winslow, Greenburg, and Reeves, the results of which were published in 1920.[1] These studies were made in automobile plants where parts too large for mechanical sandblasting are blown by hand in chambers or cabinets of sheet iron, with perforated floor, a fan to draw the air down, and an opening in the roof for the inlet of air. These cabinets are used also in the sandblasting of sanitary ware. The sand is forced by compressed air through a hose and nozzle against the metal surface, which it cleans and roughens slightly, so that it looks no longer shiny but frosted. The force of the blast is great enough to fracture the particles of sand, which grow finer and finer with each using and at last must be rejected and fresh sand brought. The coarse particles fall through the slotted floor and are recovered, the fine are partly drawn off by an exhaust, but much dust escapes and remains suspended in the air for some time. In the automobile shops the pressure in the sand blast was not over 25 pounds, but in sanitary ware shops it may be as high as 65 pounds.

Winslow and his colleagues used a Palmer water spray apparatus placed at the level of the blower's head while work was in progress. They took ten samples which showed an average, per cubic foot of air, of 60,880,000 particles of one-fourth standard (particles below one-half standard down to the limit of visibility under a magnification of 84 diameters). This is so far the only quantitative estimation that has been made of dust hazard in sandblasting; it shows figures far in excess of any found up to now in industry except in two abrasive factories studied by the same observers,[2] where the average dust content per cubic foot was, in one, 31,000,000, and in the other, 159,780,000.

They summarize their findings as follows:

> In most industrial plants the protection of the worker against the hazard of industrial dusts can be best accomplished by keeping the dust content of the air of the workroom itself down to a reasonable level. . . . .
>
> In other industrial processes, as in . . . . sand blasting of large castings, it is impossible to render the general air of the work place sufficiently free from dust to avoid danger of injury to the respiratory tract of the worker. In such cases as this, protection against the dust hazard can only be attained by the wearing of helmets, masks, or respirators, which will either filter out the dust particles from the air before it is drawn into the respiratory

[1] Winslow, C.-E. A., Greenburg, L., and Reeves, E. H.: The Efficiency of Certain Devices Used for the Protection of Sand Blasters against the Dust Hazard. U. S. Pub. Health Rep., 1920, *35*, 518.

[2] Winslow, C.-E. A., Greenburg, L., and Greenberg, D.: The Dust Hazard in the Abrasive Industry. U. S. Pub. Health Rep., 1919, *34*, 1171.

tract, or exclude the surrounding air more or less completely from the nose and mouth and supply pure air for breathing from some other source.

In sanitary ware manufacture, silica dust is encountered first in the cleaning and finishing department when the ware comes from the mold with sand still clinging to it. The looser sand is shaken off by a mechanical jolter, in the larger plants, the "dead sand" which sticks is brushed off by hand with a stiff brush, then the rough places are ground or dressed with a small carborundum wheel. The mold sand contains free silica, although it is not nearly so rich in it as is the sand used by the blowers.[3] The dust produced by this cleaning is not at all excessive, but the work is frequently done in the shop into which the sand blast chambers open. This is true in four of the largest plants and since the doors of the chambers in these plants are not closed while blowing is going on, there is an enormous escape of sand dust into the air around the ware cleaners, who are thus exposed to a danger not at all inherent in their work. Conditions in these rooms are very bad, and it must be remembered that the dust is fine silicious sand.

In one of these plants there are eight sand blast chambers, which at the time of my visit were all in operation and all opening by wide doors into one end of the ware cleaning room. The blowers could be seen only dimly through the clouds of sand which whirled around them and out into the room, although all of it did not reach the cleaners because a long hood of corrugated iron runs along the tops of the chambers like a low porch and this holds back some of the dust. The noise of the blast is deafening. In a second plant the room for cleaning large ware has six chambers opening into it, and the one for small ware, three; in a third plant there are no less than fifteen such open chambers. The sand is under a pressure of from 25 to 65 pounds.

The best equipment by far is in a large plant where the ware from the foundry is first placed on an automatic jolter over a pit covered with an iron grating to catch the coarse sand. Then it goes on a conveyor into a long tunnel where an automatic sand blast blows off the "dead sand," which falls through a slotted floor. The tunnel is equipped with an exhaust to carry off the finer sand. Even the placing and removing of ware is mechanical. This is the only plant that has an entirely satisfactory ware cleaning department. Some 700 to 725 men are employed as cleaners and grinders in the ten plants.

The "finished" ware still must undergo a much more thorough cleaning to prepare it for enameling and this is done with the sand blast. Sand very rich in silica is chosen, one plant bringing almost pure silica sand all the way from Monterey for the purpose. "Blowing," as it is called, is done inside chambers of varying degrees of excellence. In only the four plants mentioned above are the doors left open, but in another the doors leak badly and in most of the others the opening of the chamber to remove the ware is followed by the escape of a great deal of dust. There is a slotted floor inside, to catch the heavier

[3] Sand used in iron foundries usually contains from 50 to 70 per cent. of silica.

sand, and an effort is made to carry off the lighter particles by means of exhausts, but it cannot, from the nature of the work, amount to much. In the more modern plants very good mechanical devices are provided for moving the large heavy ware, but in the older ones this must be done by hand.

The work of the blower is so trying that he is never expected to carry on without intervals of rest, when he can remove his helmet, get a free breath of air, and recover from the din of his machine. In one plant he takes turns with his helper, whose work it is to get the ware in and out of the chamber. In another, the blower works an hour and takes an hour off; in a third he blows only every other day. The hours vary. In the best plant there is a day of only five and a half hours, others have six hours, seven and a half, eight, eight and a half, and one has a nine-hour day, all without any break for lunch.

As an outsider watches the work in one of those plants where the open doors permit, it seems unhealthful and exhausting to an unusual degree. The roar of the blast, the dense whirling clouds of sand, the dim light which can pierce the clouds only faintly, make a picture not often seen in modern industry and one with serious implications, because of the nature of the dust and the fact that, being driven with such force, it can penetrate the usual kinds of protective covering. The blower is always protected against the bombardment of the sand particles by a helmet of heavy canvas or ticking which drops down below his neck and is loosely tied, but this must have a window to let him look through, and the only practical kind seems to be one of fine copper mesh, which cannot keep out the finer particles of dust because they are driven with such great pressure. I have never failed to detect sand in the inside of one of these helmets if I examined it just after use. Because of this fact some employers provide in addition to the helmet an ordinary muzzle respirator with a sponge. In most plants the helmet has an air pipe which opens either at the back or in front near the window or through an aluminium plate on the top, and which provides fresh air by positive pressure, usually from the compressed air supply. In five plants such helmets are in use and also a muzzle respirator. Three use only the helmet, and one has helmet and respirator but no air pressure. The tenth and best has air delivered through the respirator, not the helmet, which latter is worn simply for mechanical protection. The air in this case does not come from the compressed air line but is delivered under low pressure at room temperature through a Reed air filter. Such an arrangement certainly fulfils the requirements for safeguarding the sand blaster better than any other yet seen.

The helper is exposed to almost as much dust as the blower, when he works just outside an open chamber, yet he has no protection except a muzzle respirator which he rarely uses, never continuously. In the other plants there is less constant exposure but he is close to the chamber when it opens and he goes inside to place the ware and to remove it. There are about 200 blowers in these ten plants and about 130 helpers.

The notoriously dangerous charac-

ter of the sand blaster's work led the largest of the sanitary ware companies to experiment for many years in the hope of making the work mechanical and a large number of devices have been installed, tested, but usually found unsatisfactory. The problem is a difficult one to solve, for unless the ware is absolutely free from imperfections and from grease, the enamel will not hold, and it is hard to make a machine which will not miss some little area of the surface. In three of the plants operated by this company, automatic blowers have been installed, but I saw them working in only one. There are three machines for large ware, one for small. The room in which the former are placed is large and amply ventilated. The ware goes slowly along a conveyor through a small blast chamber in which sand is blown through movable nozzles, and out of which it emerges through an opening protected by curtains. So far it is impossible to prevent a good deal of sand being driven out through this opening, but the machine is certainly a great improvement over handwork. It has been found better to have the nozzles of the sand blast turn and twist over a horizontal tub than to have the ware mechanically turned.

This reform was introduced for the sake of the sand blasters, not primarily for economy, since the saving effected is not great. One hand blower can clean sixty-five tubs in an eight-hour day, with one-third of a helper's time added, which makes an average of forty-nine tubs per man. By machine, one operator, two feeders, and two takers-off can clean 300 tubs in eight hours, an average of sixty tubs per man.

The substitution of steel shot for sand has been found both practical and economical in a number of manufacturing establishments which prepare iron for coating, and this method does away almost entirely with the danger of silicosis, for the only sand is that which adheres to the metal from the mold. Several enameling companies have tried shot blast but all say that it does not give good results; it drives in the scale instead of cleaning it off and does not leave an unblemished surface for the enamel. The only use for the shot blast is to clean enamel from "seconds," *i.e.*, imperfect ware which is to be reenameled.

A very necessary step in the prevention of silicosis has already been taken in three plants, where the men are examined not only for employment but at regular intervals as long as they are employed in sandblasting. Two other plants have decided to follow this program. It is to be hoped that the system will be extended to ware cleaners and to blowers' helpers, as is at present done in two of the three factories mentioned above. The experience in establishments that have dealt seriously with the problem of silicosis shows that it can be prevented only by careful selection of the men at the beginning and then frequent examination including X-ray pictures in order to detect the early stages of silicosis and remove the man from further exposure. For sand blasters this should be done every six months; for helpers and cleaners a longer interval may be allowed. The one sanitary ware plant which has followed this system for some time uses a further precaution in that the blower is allowed only six months' consecutive work and then

six months in other work before sandblasting can be resumed.

Statistics furnished by the Metropolitan Life Insurance Company show that the tuberculosis death rate of negro men insured in the industrial department is far higher than the death rate from this disease of white men in the same class. The figures for workers between 20 and 40 years of age are as follows:

*Tuberculosis Death Rates*

| *Age* | *Whites* | *Negroes* |
|---|---|---|
| *yrs.* | *per 100,000* | |
| 20–24 | 100.4 | 316.7 |
| 25–29 | 132.1 | 298.6 |
| 30–34 | 139.2 | 293.7 |
| 35–39 | 172.0 | 292.5 |

Negroes, therefore, seem to constitute a poor risk in an occupation involving danger of silicosis and it is a fact to be deplored that so many are employed as cleaners of sanitary ware and as sand blasters or helpers. Of 720 ware cleaners, 212 are negroes; of 330 sand blasters and helpers, 160 are negroes.

## Summary

Comparing conditions in *mixing enamel and enameling* in 1927 to 1928 with those in 1911 to 1912, the improvements found are:

1. The enamel contains less lead and to an increasing extent is free from lead.
2. There is less dust in the mills.
3. There is less dust in enameling.
4. Work at the furnaces is much less heavy and somewhat less hot.
5. Washing facilities are adequate, sometimes luxurious.
6. Routine medical service has already been installed in five plants, and is about to be installed in a sixth.
7. There is a low labor turnover and careful attention to the individual workman.

The evils still remaining are as follows:

1. Lead content of enamel may still reach 10 per cent. or may even exceed this figure.
2. In mills where lead oxide is used there is still far too much dust.
3. The enameler still works six to eight hours with no pause and eats his lunch at his workplace, even in plants where lead enamel is used.
4. Dry sweeping is still universally used.
5. Medical examination to detect lead poisoning in the early stages is still lacking in many plants.

Conditions found in *ware cleaning* in 1927 to 1928 are as follows:

Some 200 hand blowers, 130 helpers, 15 machine blowers, and 720 cleaners and finishers in nine plants, a total of 1,065 men, are employed in work which exposes them to the inhalation of dust finely divided and rich in free silica.

The hand blowers are protected by:

Helmet with respirator, no positive pressure—one plant.

Helmet with positive pressure, no respirator—three plants.

Helmet with positive pressure, respirator—five plants.

Helmet, and respirator with positive pressure—one plant.

Blowers' helpers are provided with muzzle respirators only, and these are seldom worn.

There is no protection for cleaners and finishers when the dust is excessive.

In a study made by Winslow, Greenburg, and Reeves an average of ten

samples of air taken in sand blast chambers yielded, per cubic foot of air, 60,880,000 particles of dust below one-half standard. No estimate has been made of the dust content of ware cleaning and finishing rooms but it is probably fairly high, certainly in those rooms which communicate directly with open sand blast chambers.

Proper protection of these men involves:

1. Closing all sand blast chambers and rendering them dust proof.

2. Careful selection of helmet and respirator. At present the best type available is a respirator with positive pressure and a helmet for mechanical protection.

3. Examination on employment and each six months thereafter of blowers, with yearly examination of helpers, ware cleaners, and finishers.

During the years that the sanitary ware industry has been losing its dangers a new industry has grown up resembling it in many ways, and that is the enameling of kitchen stoves and gas ranges. The only investigation so far in this field was made by Leathers and Morgan[4] in a plant using enamel which contained "more than the usual percentage of lead and some cadmium" and which was applied from spray guns operated under 80 pounds of pressure. Thirty-nine employees were examined for plumbism and a definite diagnosis made in fifteen cases (39 per cent.); a probable diagnosis was made in eleven more (28 per cent.). In this plant only men were employed but in many stove works women do much if not all of the spraying. This is an industry which should be made the subject of a thorough investigation in the near future.

[4] Leathers, W. S., and Morgan, H. J.: The Study of Lead Poisoning in an Enameling Plant. Jour. Am. Med. Assn., 1927, *89*, 1107.

## Appendix

The British Regulations for vitreous enameling of metal or glass came into force April 1, 1909. The chief provisions are as follows:

### Definitions.

"*Enamelling*" means crushing, grinding, sieving, dusting or laying on, brushing or woolling off, spraying, or any other process for the purpose of vitreous covering and decoration of metal or glass;

"*Employed*" means employed in *enamelling;*

"*Surgeon*" means the Certifying Factory Surgeon of the district or a duly qualified medical practitioner appointed by written certificate of the Chief Inspector of Factories, which appointment shall be subject to such conditions as may be specified in that certificate;

"*Suspension*" means suspension by written certificate in the Health Register, signed by the *Surgeon*, from employment in any *enamelling* process.

### Duties.

It shall be the duty of the occupier to observe Part I. of these Regulations.

It shall be the duty of all persons *employed* to observe Part II. of these Regulations.

### Part I.

### Duties of Employers.

1. Every room in which any *enamelling* process is carried on—

(*a*) shall contain at least 500 cubic feet of air space for each person *employed* therein, and in computing this air space no height above 14 feet shall be taken into account;

(*b*) shall be efficiently lighted, and shall for this purpose have efficient means of lighting both natural and artificial.

2. In every room in which any *enamelling* process is carried on—

(*a*) The floors shall be well and closely laid, and be maintained in good condition;

(*b*) The floors and benches shall be cleansed daily and kept free of collections of dust.

3. No *enamelling* process giving rise to dust or spray shall be done save either—

(*a*) under conditions which secure the absence of dust and spray; or

(*b*) with an efficient exhaust so arranged as to intercept the dust or spray and prevent it from diffusing into the air of the room.

4. Except in cases where glaze is applied to a heated metallic surface, dusting or laying on, and brushing or woolling off, shall not be done except over a grid with a receptacle beneath to intercept the dust falling through.

5. If firing is done in a room not specially set apart for the purpose, no person shall be employed in any other process within 20 feet from the furnace.

6. Such arrangements shall be made as shall effectually prevent gases generated in the muffle furnaces from entering the workrooms.

7. No child or young person under 16 years of age shall be *employed* in any *enamelling* process.

8. A Health Register, containing the name of all persons *employed*, shall be kept in a form approved by the Chief Inspector of Factories.

9. Every person *employed* shall be examined by the *Surgeon* once in every three months (or at such other intervals as may be prescribed in writing by the Chief Inspector of Factories) on a date of which due notice shall be given to all concerned.

10. The *Surgeon* shall have power of *suspension* as regards all persons *employed*, and no person after *suspension* shall be *employed* without written sanction from the *Surgeon* entered in the Health Register.

11. There shall be provided and maintained for the use of all persons *employed*—

(*a*) suitable overalls and head-coverings, which shall be collected at the end of every day's work, and be cleaned or renewed at least once every week;

(*b*) a suitable place, separate from the cloakroom and mealroom, for the storage of the overalls and head-coverings;

(*c*) a suitable cloakroom for clothing put off during working hours;

(*d*) a suitable mealroom separate from any room in which *enamelling* processes are carried on, unless the works are closed during meal hours.

12. There shall be provided and maintained in a cleanly state and in good repair, for the use of all persons *employed*, a lavatory, under cover, with a sufficient supply of clean towels, renewed daily, and of soap and nail brushes, and with either—

(*a*) a trough with a smooth impervious surface, fitted with a waste pipe without plug, and of such length as to allow at least two feet for every five such persons, and having a constant supply of warm water from taps or jets above the trough at intervals of not more than two feet; or

(*b*) at least one lavatory basin for every five such persons, fitted with a waste pipe and plug or placed in a trough having a waste pipe, and having either a constant supply of hot and cold water or warm water laid on, or (if a constant supply of heated water be not reasonably practicable) a constant supply of cold water laid on and a supply of hot water always at hand when required for use by persons *employed*.

13. The occupier shall allow any of H. M. Inspectors of Factories to take at any time sufficient samples for analysis of any *enamelling* material in use or mixed for use.

Provided that the occupier may at the time when the sample is taken, and on providing the necessary appliances, require the Inspector to take, seal and deliver to him a duplicate sample.

No results of any analysis shall be published without the consent of the occupier, except such as may be necessary to prove the presence of lead when there has been infraction of the Regulations.

## Part II.

### Duties of Persons Employed.

14. Every person *employed* shall—

(*a*) present himself at the appointed time for examination by the *Surgeon* as provided in Regulation 9;

(*b*) wear the overall and head-covering

provided under Regulation 11 (*a*), and deposit them and clothing put off during working hours, in the places provided under Regulation 11 (*b*) and (*c*);

(*c*) carefully clean the hands before partaking of any food or leaving the premises;

(*d*) so arrange the hair that it shall be effectually protected from dust by the head-covering.

15. No person *employed* shall—

(*a*) after *suspension*, work in any *enamelling* process without written sanction from the *Surgeon* entered in the Health Register;

(*b*) introduce, keep, prepare, or partake of any food, drink, or tobacco, in any room in which an *enamelling* process is carried on;

(*c*) interfere in any way, without the concurrence of the occupier or manager, with the means and appliances provided for the removal of dust or fumes, and for the carrying out of these Regulations.

# EXPERIMENTAL ELECTRIC SHOCK. II.*

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## Introduction

In a previous paper by one of us[1] it has been noted that in laboratory animals when an alternating current of definite strength is passed directly through the base of the brain, for a certain period of time, a condition of profound paralysis, or block, becomes established in the nerve centers. The presence of this block was demonstrated by experiments in which reflex effects normally functioning through these centers (respiratory, vagal, and conjunctival) were found to be absent following the shock. It was further shown that, after a certain interval following break of the electric current, the paralysis or block is recovered from and the reflexes return, provided efficient artificial respiration is meanwhile applied and provided there has been no charring of the nerve structures.

The present paper deals with further studies on the production and nature of this block. Since it is produced by the passage of an alternating current, the term "a-c block" has been applied, to differentiate it from a somewhat similar condition produced in the nerve by the passage of the direct current—the so-called anelectrotonus.

In the first part of the paper experiments are recorded to show that a definite block occurs following the passage of the alternating current through the cardinal centers of the brain at all the frequencies met with in ordinary industrial practice. Then follow experiments to determine the relative efficiency of using air, or oxygen, or oxygen and carbon dioxide mixtures during artificial respiration as well as experiments to determine whether any advantage is gained by using adrenaline. Finally, the question of relapse following resuscitation is investigated, since it is the general impression that this frequently happens in field practice.

The second part of the paper deals with a study of a-c block as it can be produced in the spinal cord. The technical difficulties in this type of experiment were found to be not easily overcome, but eventually a technic was established which gave fairly consistent results.

The third part of the paper is concerned with a-c block in nerve. This was investigated by means of a modified nerve-muscle preparation, and evidence is submitted to indicate some of the essential features of a-c block in nerve.

*Received for publication Feb. 8, 1929.

[1] Urquhart, R. W. I.: Experimental Electric Shock. This Jour., 1927, *9*, 140.

### A-C Block in the Cardinal Centers

The fundamental observations on a-c block in the cardinal centers may be briefly summarized from the previous paper:

1. When an alternating current of 1,100 milliamperes, or over, is passed for two seconds through the brain of an animal by means of a special point electrode in the nose and a large button electrode (area 0.36 sq. cm.) on the atloido-occipital membrane, death occurs because of respiratory failure.

2. If artificial respiration is applied within from one to five minutes following break of the current, recovery usually takes place provided the current has not been of pithing caliber (which is roughly over 1,700 milliamperes with the electrodes applied as above).

3. Stimulation of the central end of one vagus nerve is without reflex effect on the heart for some minutes after the shock, but the reflexes return following respiratory recovery. This is interpreted as evidence that block becomes established at the vagus center as a result of the passage of the current.

Electrical equipment identical with that previously used was employed, a diagram of which is to be found in the previous paper. The procedure was as follows: The animal was anesthetized and cannulas were inserted in the trachea and into the carotid artery so that records of the blood pressure could be obtained. In some instances, cannulas in the femoral artery were used, to obviate certain mechanical irregularities which were found to occur when tracings were taken from the carotid. One of the vagus nerves was isolated and severed at the level of the cricoid cartilage, and arranged so that the central end could be stimulated by weak induction shocks. The atloido-occipital membrane was then exposed, the special button electrode was placed in position, and the point electrode inserted in the nose. After the animal had recovered sufficiently from the anesthetic so that the eye reflex could be elicited, and after sufficient records of reflex vagus activity had been obtained, the desired current was applied through the brain for two seconds. The vagus was stimulated at intervals throughout the period of apnea and following respiratory recovery. The results are recorded in Table 1 and in Charts 1, 2, and 3.

It will be noted that, in the majority of instances, the vagal response, previous to electrocution, showed itself in a slight fall in blood pressure, which is indicated in the table by the direction of the arrow, resulting partly from a reflex slowing of the heart and probably also from reflex vasodilatation. The electrocution current varied from 1,200 to 1,850 milliamperes. It was applied in all cases for two seconds and artificial respiration was commenced as soon as possible after it was broken. Normal respiration returned at varying intervals up to three and a half minutes. The pupillary reflex and the vagal response returned decidedly later than the breathing, and they were obtained in the majority of instances either at the same time, or within a few seconds of each other. These results would indicate that the block in these experiments was relatively short and this is to be accounted for by the fact that artificial respiration was applied immediately after the circuit was broken.

Wills Maclachlan[2] has pointed out that a considerable interval, almost always from three to four minutes, elapses before artificial respiration can be applied in accidents in the field, so that it becomes of considerable clinical importance to see whether any measures could be employed to reduce the period of block which ensues following the passage of the current. In order to test the relative efficiency of such measures, it was necessary first of all to find a standardized method of experiment in which the only variable would be the remedial agent. It had previously been found impossible to apply a current of such strength that, without producing charring of the nervous tissues, it would so injure the respiratory center that artificial respiration was ineffective. It was also found impossible to use the rate of recovery following nonpithing currents as a basis for comparison, on account of great variability in rate.

The method finally adopted consisted in first of all determining in a series of control experiments the length of interval following break of the shock, beyond which artificial respiration with air would not result in resuscitation, and then seeing whether this interval could be prolonged when oxygen or oxygen and carbon dioxide

TABLE 1.—RESULTS OF EXPERIMENTS DEMONSTRATING A-C BLOCK IN THE VAGUS CENTER

(*Artificial respiration applied immediately following the shock.*)

| ANIMAL NO. | REFLEX VAGAL RESPONSE PRECEDING CURRENT[1] | CURRENT APPLIED FOR 2 SECONDS | RETURN OF NORMAL RESPIRATION | RETURN OF PUPILLARY REFLEX | RETURN OF REFLEX VAGAL RESPONSE |
|---|---|---|---|---|---|
| | | *milliamp.* | *min./sec.* | *min./sec.* | *min./sec.* |
| Rabbit 4 | B.P. ↓ (Carotid) | 1,500 | 2/– | 2/– | 2/– |
| " 4B[2] | B.P. ↓ " | 1,500 | 2/– | 6/40 | 6/42 |
| " 6 | B.P. ↓ " | 1,300 | 2/– | 5/30 | 4/– |
| " 6B | B.P. ↓ " | 1,500 | 1/15 | 2/– | 4/– |
| " 6C | B.P. ↑ " | 1,700 | 1/– | 2/– | 3/– |
| " 6D[3] | B.P. ↑ (Femoral) | 1,850 | 3/30 | 9/– | 9/– |
| Cat 2 | B.P. ↓ (Carotid) | 1,500 | 1/30 | 2/– | 2/– |
| " 2B[4] | B.P. ↓ " | 1,600 | 1/30 | 2/30 | 2/30 |
| " 2C | B.P. ↓ " | 1,700 | 1/15 | 3/– | 3/– |
| " 3 | B.P. ↓ " | 1,800 | 1/– | 7/– | 7/– |
| " 6 | B.P. ↓ " | 1,200 | –/30 | 1/– | 1/– |
| " 6B | B.P. ↓ " | 1,460 | 1/30 | 2/– | 2/– |
| " 6C | B.P. ↓ " | 1,260 | 1/– | 1/30 | 1/30 |
| " 6D | B.P. ↓ " | 1,650 | 1/30 | 2/– | 2/– |

[1] The arrow represents the direction of blood pressure change as a result of reflex vagal response.

[2] Chart 1.

[3] Chart 2.

[4] Chart 3.

[2] Personal communication.

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TABLE 1.—RESULTS OF EXPERIMENTS DEMONSTRAT THE VAGUS CENTER

(*Artificial respiration applied immediately following*

| ANIMAL NO. | REFLEX VAGAL RESPONSE PRECEDING CURRENT[1] | CURRENT APPLIED FOR 2 SECONDS | RETURN OF NORMAL RESPIRATION | | |
|---|---|---|---|---|---|
| | | *milliamp.* | *min./sec.* | | |
| Rabbit 4 | B.P. ↓ (Carotid) | 1,500 | 2/– | | |
| " 4B[2] | B.P. ↓ " | 1,500 | 2/– | | |
| " 6 | B.P. ↓ " | 1,300 | 2/– | | |
| " 6B | B.P. ↓ " | 1,500 | 1/15 | | |
| " 6C | B.P. ↑ " | 1,700 | 1/– | | |
| " 6D[3] | B.P. ↑ (Femoral) | 1,850 | 3/30 | | |
| Cat 2 | B.P. ↓ (Carotid) | 1,500 | 1/30 | | |
| " 2B[4] | B.P. ↓ " | 1,600 | 1/30 | | |
| " 2C | B.P. ↓ " | 1,700 | 1/15 | | |
| " 3 | B.P. ↓ " | 1,800 | 1/– | | |
| " 6 | B.P. ↓ " | 1,200 | –/30 | | |
| " 6B | B.P. ↓ " | 1,460 | 1/30 | | |
| " 6C | B.P. ↓ " | 1,260 | 1/– | | |
| " 6D | B.P. ↓ " | 1,650 | 1/30 | 2/– | 2/– |

[1] The arrow represents the direction of blood pressure change as a result of reflex vagal response.

[2] Chart 1.

[3] Chart 2.

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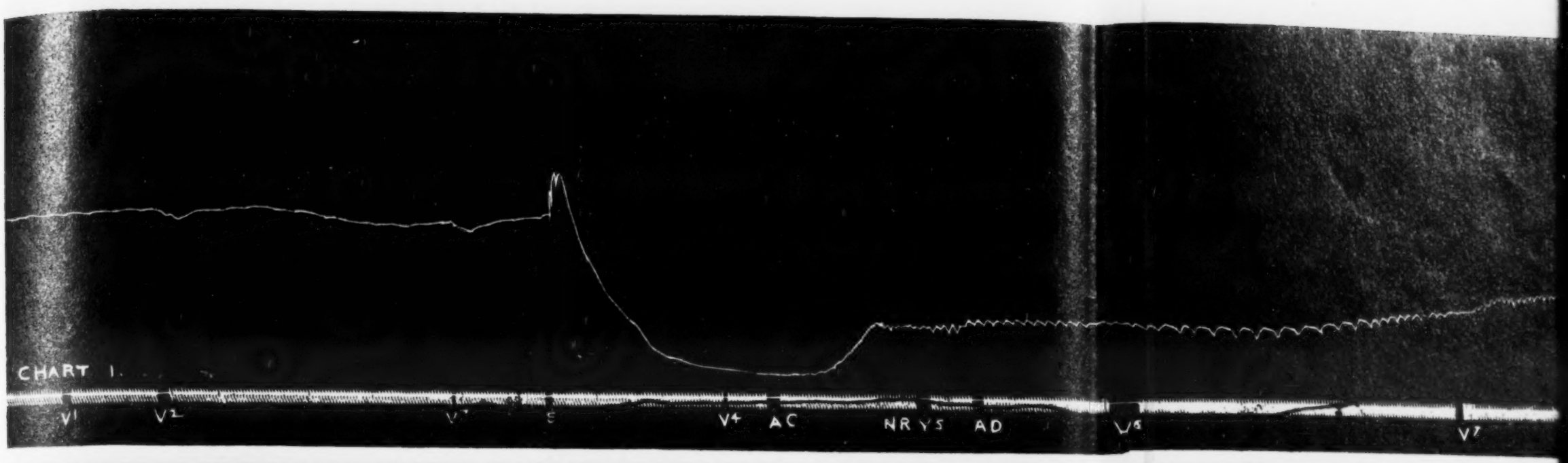
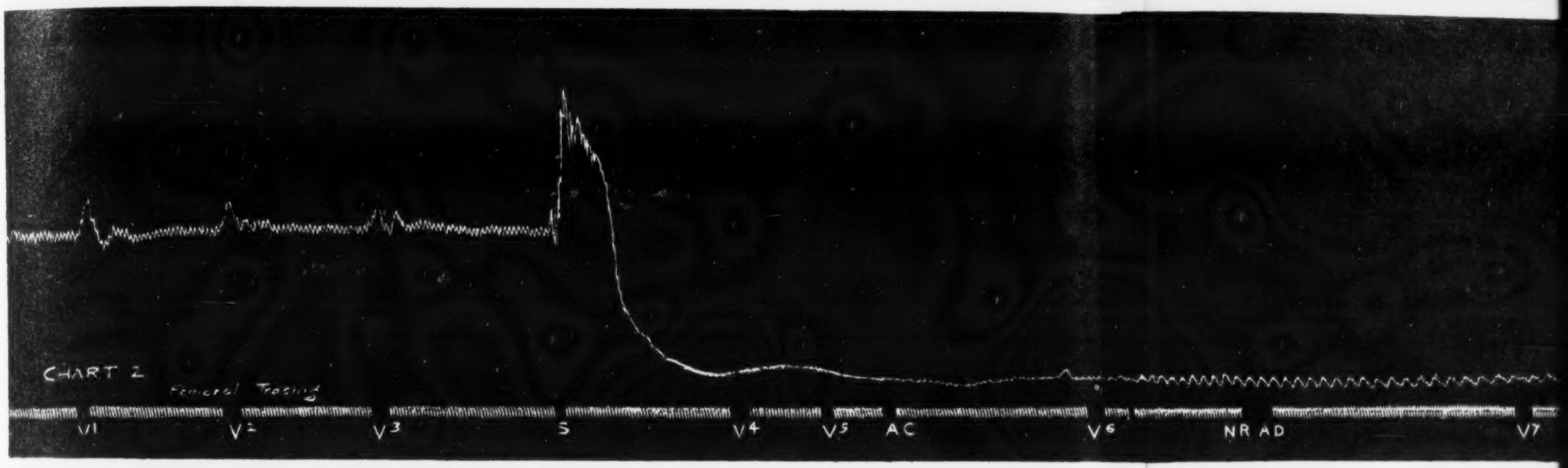
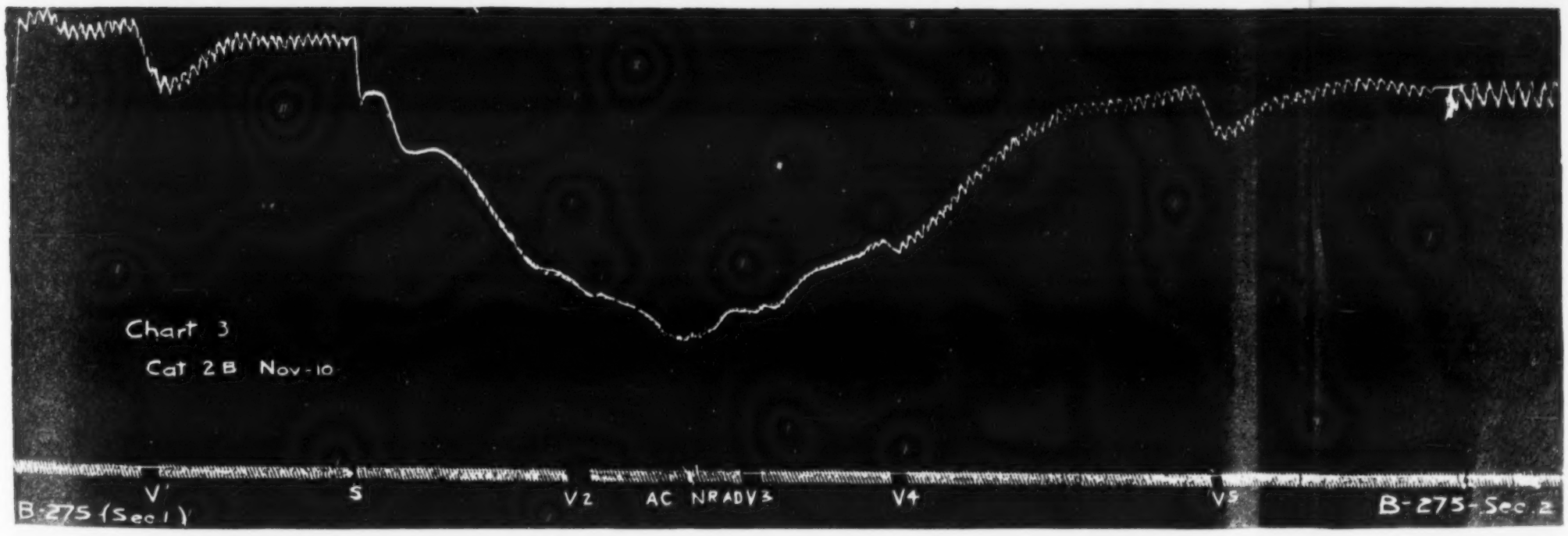
The method finally adopted consisted in first of all determining in a series of control experiments the length of interval following break of the shock, beyond which artificial respiration with air would not result in resuscitation, and then seeing whether this interval could be prolonged when oxygen or oxygen and carbon dioxide



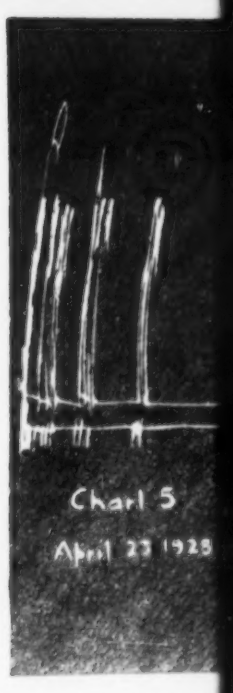




Chart 1.—Rabbit 4 B. Demonstrating the presence of a-c block in the vagus center. Electrodes on the atloido-occipital membrane and recorded in seconds on blood pressure base line.

$V^1$, $V^2$, etc. = stimulation of central end of cut vagus. S = shock. AC = artificial respiration commenced. AD = artificial respir

*Note.*—At $V^6$ and $V^7$ it will be observed that there is interference with the blood pressure tracing at the time of vagal stimulation. This wa

Chart 2.—Rabbit 6 D. Demonstrating the presence of a-c block in the vagus center. Electrodes on the atloido-occipital membrane ar in Chart 1.

$V^1$, $V^2$, S, AC, AD, and NR as in previous chart.

*Note.*—The reflex vagal response in this case is a rise in blood pressure.

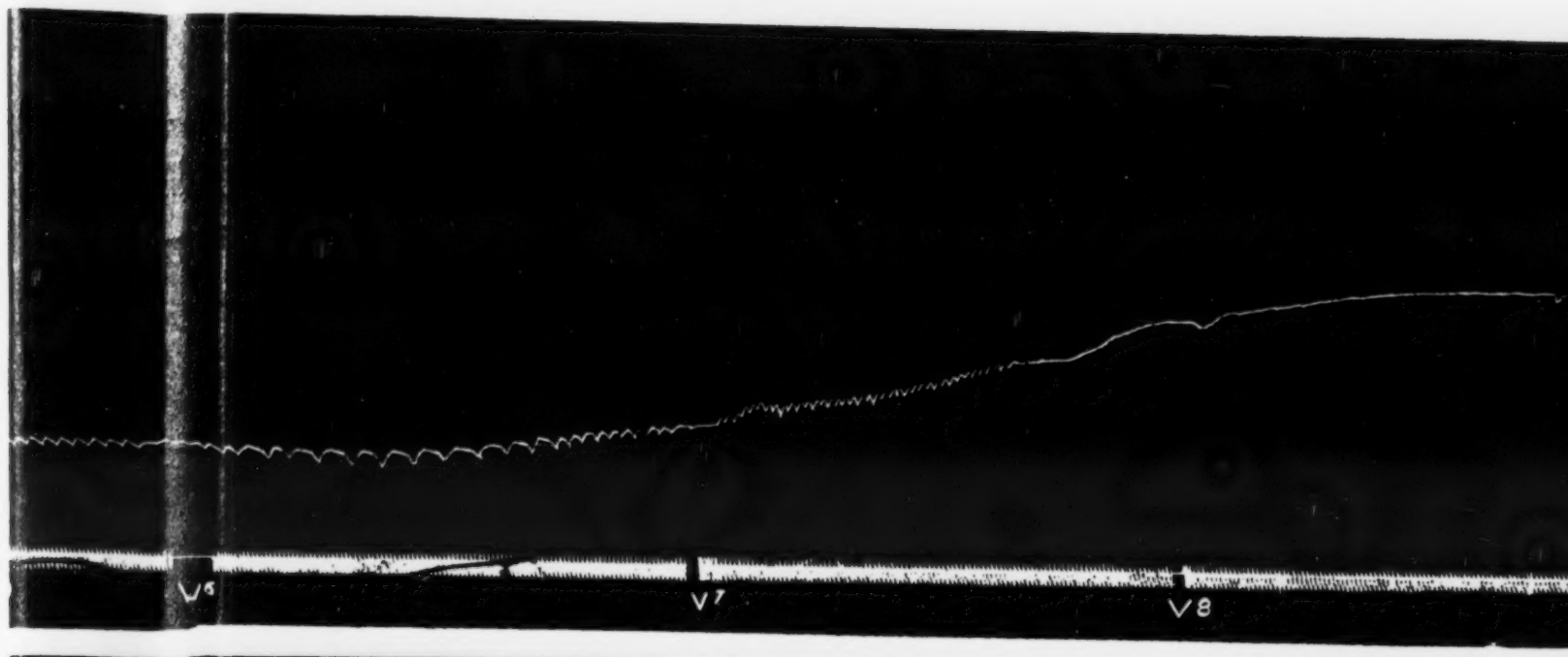
Chart 3.—Cat 2 B. Demonstrating the presence of a-c block in the vagus center. Electrodes as before. Current 1,600 milliamper

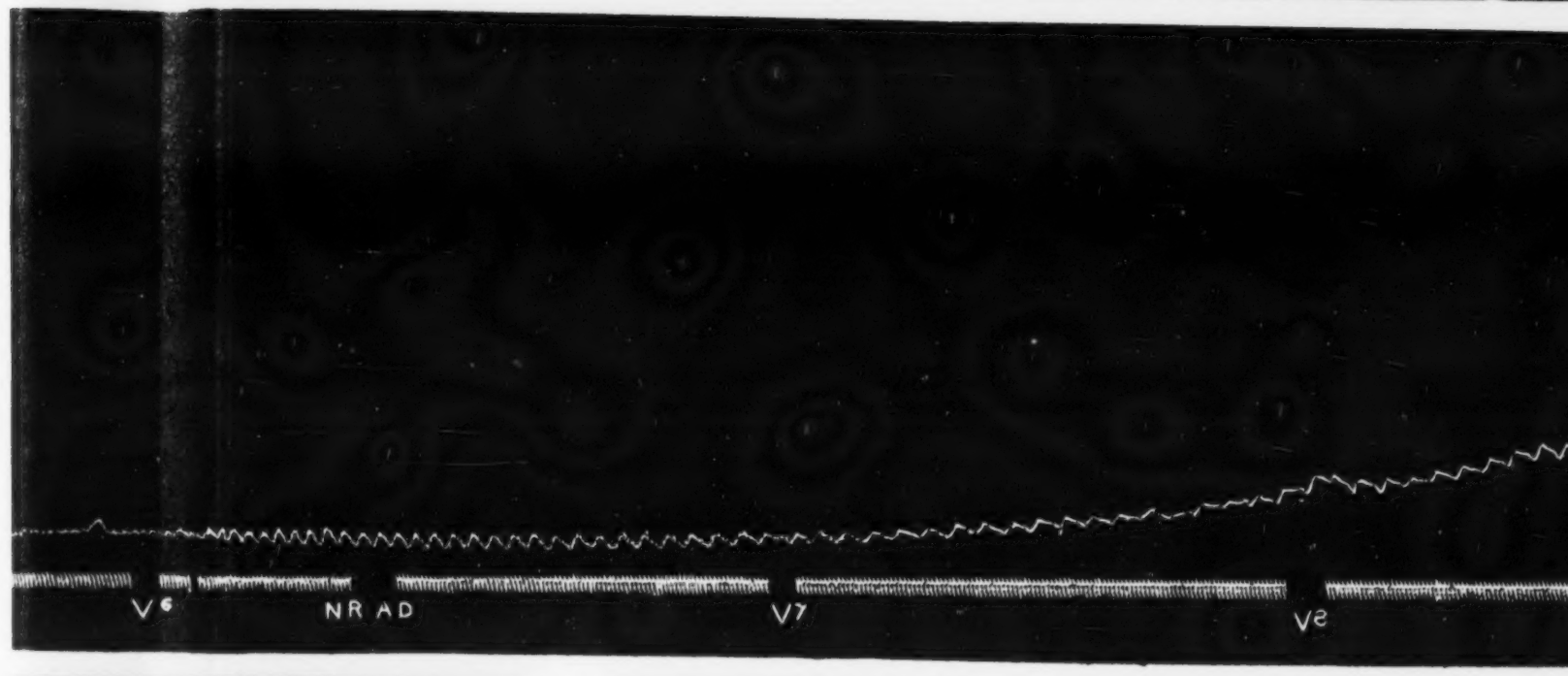
$V^1$, $V^2$, S, AC, AD, and NR as in previous charts.

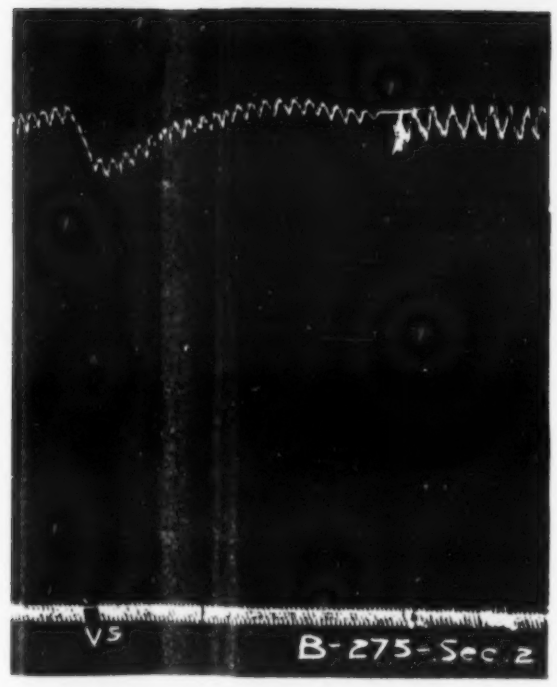
*Note.*—In all cases it is to be noted that vagus stimulation failed to have its usual effect for some time after the electrocution shock. It

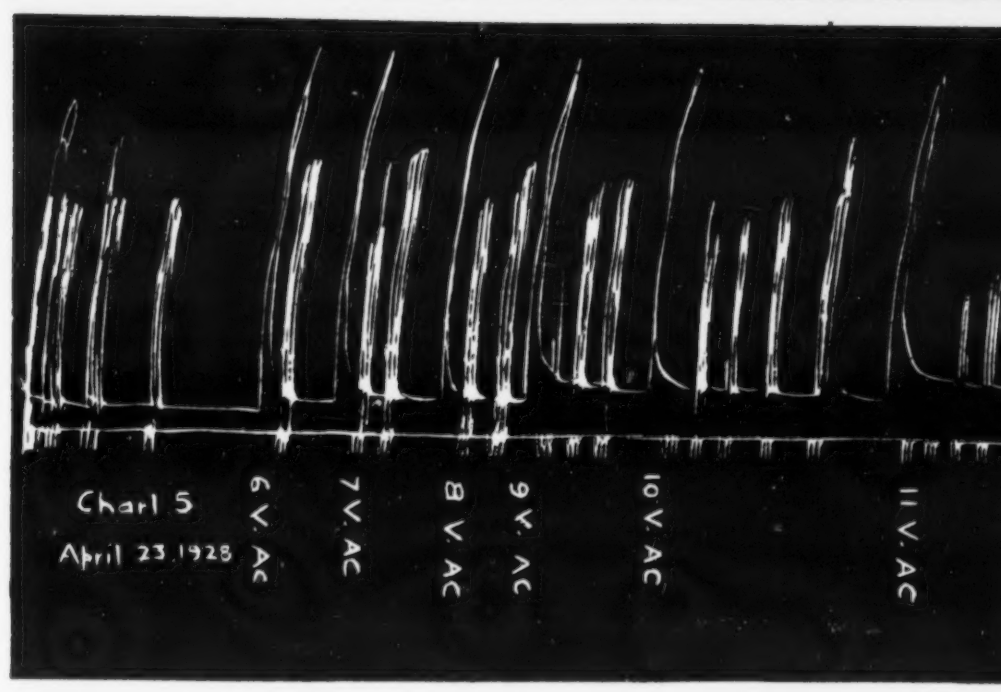
Chart 5.—Demonstrating a-c block in nerve. Nerve-muscle preparation of frog. Signals on base line are in series with stimulatin seconds; the voltage is as indicated on the chart.

*Note.*— As the alternating current is increased the resulting period of absolute block lengthens and excitability of the nerve, as indicat



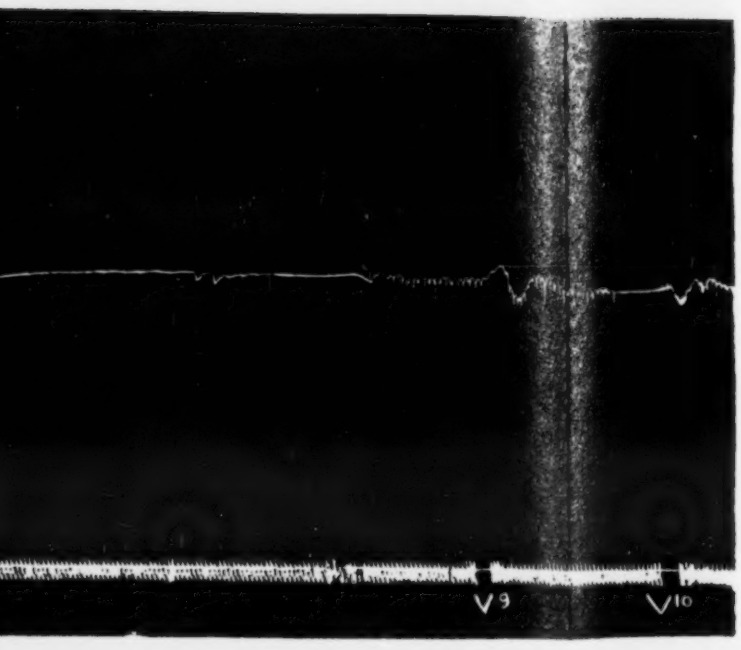

. Electrodes on the atloido-occipital membrane and in the nose. Current 1,500 milliamperes for t

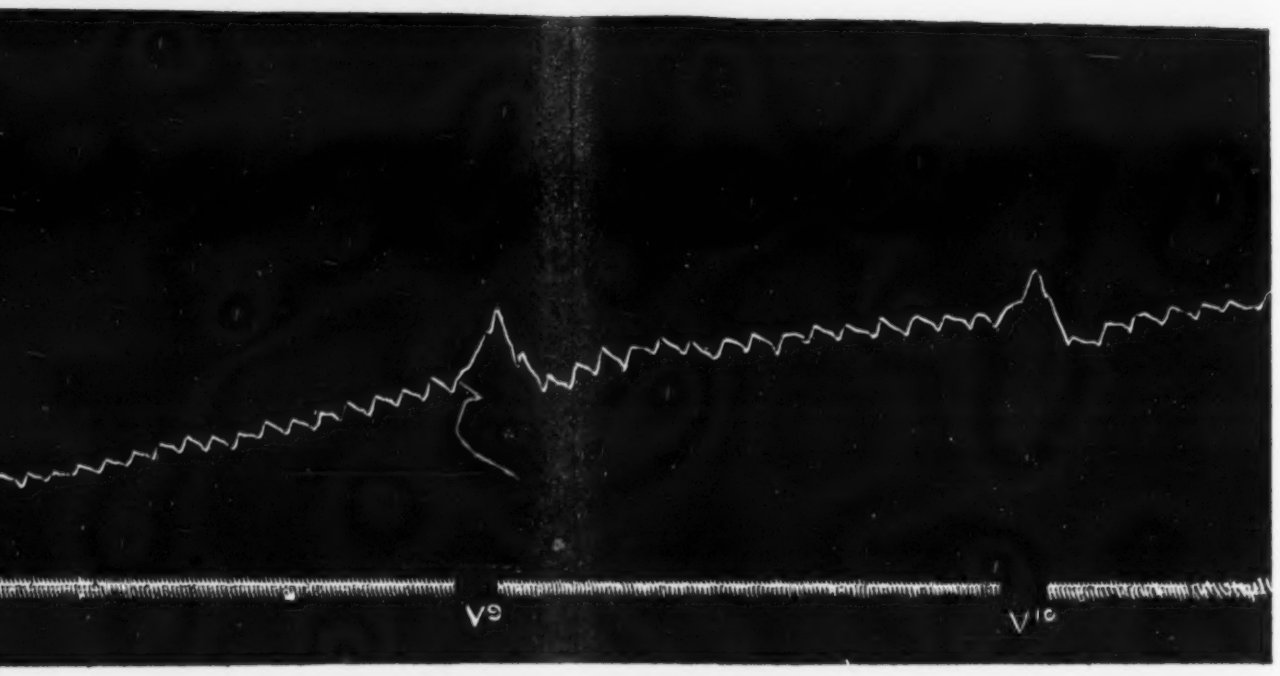
l respiration commenced. AD = artificial respiration discontinued. NR = return of nor
tracing at the time of vagal stimulation. This was found to be caused by the contraction of the
. Electrodes on the atloido-occipital membrane and in the nose. Current 1,850 milliamperes for

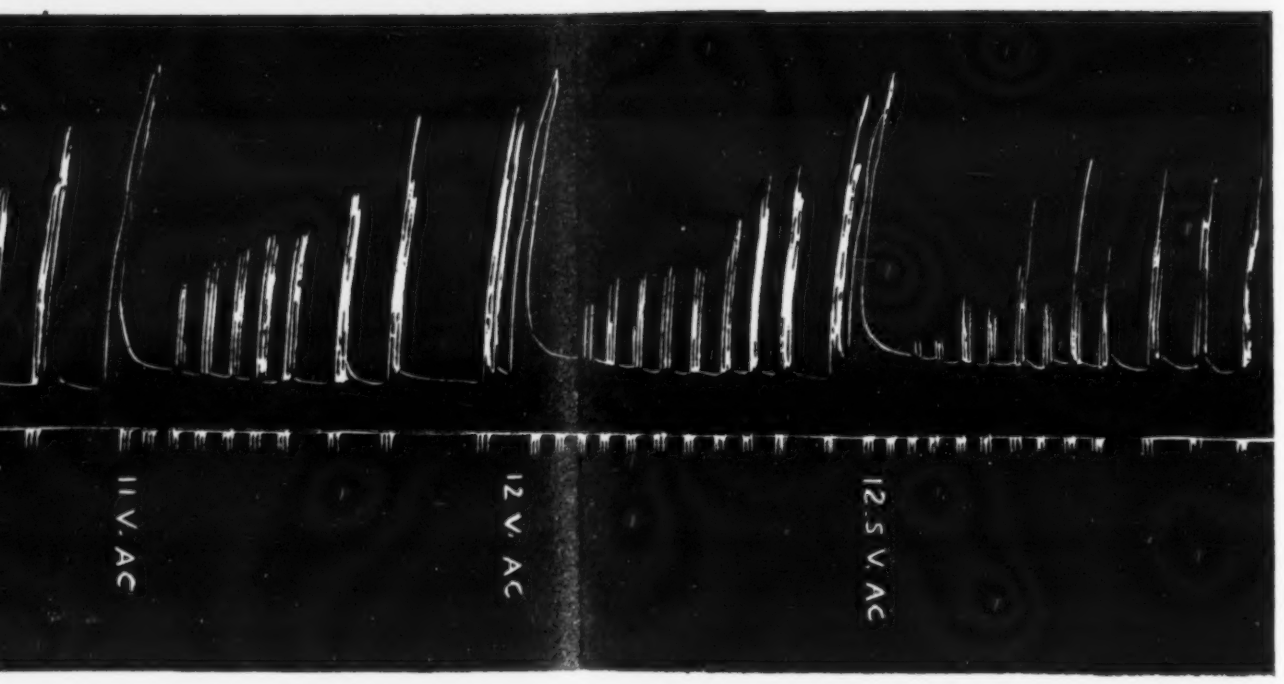
r. Electrodes as before. Current 1,600 milliamperes for two seconds. Tracing from carotid ar

t for some time after the electrocution shock. It always returned following the application of a
Signals on base line are in series with stimulating current from inductorium and indicate min

k lengthens and excitability of the nerve, as indicated by the height of contraction of attached mu




amperes for two seconds. Blood pressure tracing from carotid artery. Time

eturn of normal respiration.
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mixtures were used or when adrenaline was injected.

Table 2 contains in brief the results of this series of experiments. The current administered was constant, being 1,500 milliamperes for two seconds applied through the brain by means of the special electrodes previously described. Artificial respiration, with gas mixtures or air, was applied commencing at intervals of 2, $2\frac{1}{4}$, $2\frac{1}{2}$, and 3 minutes, respectively, after the shock. The gas mixtures were delivered from a large Tissôt spirometer through a pump to a catheter inserted in one nostril of the animal, the mouth being held closed. Irrespective of the mixture used for artificial respiration, the intervals between its application and the first normal breaths were much the same. As might be expected, the proportion of deaths increases as the interval between electrocution and artificial respiration is lengthened so that with an interval of $2\frac{1}{2}$ or 3 minutes recovery is unusual whether air, or oxygen, or a mixture of oxygen and carbon dioxide is used. Further, with an interval of $2\frac{1}{4}$ minutes, the proportion of recoveries with air is as great as with any other substance. It would therefore appear that no advantage is to be gained by the substitution of pure oxygen, or oxygen and carbon dioxide mixtures, in resuscitation from electric shock.

On account of the suggestion that the chances of recovery from electrocution are enhanced by injection of adrenaline, the effect of injections of this substance on the rate of recovery of respiration was studied. Accordingly, 1,500 milliamperes were passed through the head for two seconds as in the preceding experiments, and, as soon as possible thereafter, 5 minims of adrenaline 1:1,000 solution were injected intramuscularly. Artificial respiration was then applied at varying intervals after the shock. From Table 2 it can be seen that recovery rarely takes place when the interval between the shock and the application of artificial respiration is more than two and a quarter minutes. If the administration of adrenaline is of value, it might be expected that this interval could be prolonged and recovery still take place. In fourteen experiments in which the interval before the application of artificial respiration was extended to two and a half minutes and up to three minutes the administration of adrenaline did not seem to have any beneficial effect. Only three of the animals recovered with artificial respiration. It will be seen that these results are not unlike those recorded where adrenaline was not administered. We, therefore, believe that the administration of adrenaline, since it does not succeed in influencing the length of interval

TABLE 2.—EXPERIMENTS SHOWING THE EFFECT OF VARIATIONS IN THE INHALATION MEDIA IN ARTIFICIAL RESPIRATION

| INTERVAL BEFORE APPLICATION OF ARTIFICIAL RESPIRATION *min./sec.* | AIR | | PURE $O_2$ | | $O_2$ + 10% $CO_2$ | | $O_2$ + 6% $CO_2$ | |
|---|---|---|---|---|---|---|---|---|
| | Died | Recovered | Died | Recovered | Died | Recovered | Died | Recovered |
| 2/15 | 2 | 7 | 1 | 3 | 3 | 5 | 4 | 5 |
| 2/30 and 3/– | 4 | 2 | 6 | 2 | .. | .. | .. | .. |

after which recovery may take place, is not of value in artificial respiration.

to compare these frequencies, a standardized series of experiments should

TABLE 3.—RESULTS OF EXPERIMENTS WITH VARYING FREQUENCIES

| RABBIT NO. | CURRENT APPLIED FOR 2 SECONDS *milliamp.* | INTERVAL BEFORE APPLICATION OF ARTIFICIAL RESPIRATION *min./sec.* | INTERVAL BEFORE FIRST NORMAL BREATH *min./sec.* |
|---|---|---|---|
| | | *12.5 Cycle* | |
| 80 | 1,500 | Not applied | Died. |
| 81 | 1,500 | Not applied | Died. |
| 82 | 1,650 | –/30 | 2/– |
| 83 | 1,520 | 2/15 | 1/45 |
| 83B | 1,650 | 2/15 | Died. |
| 84 | 1,500 | 2/15 | –/15 |
| | | *60 Cycle* | |
| 85 | 1,500 | Not applied | Died. |
| 86 | 1,600 | 2/15 | 1/5 Died later. |
| 87 | 1,500 | 2/30 | 1/35 Died later. |
| 88 | 1,580 | Immediately | 1/30 |
| 89 | 1,500 | 2/15 | –/50 |
| 90 | 1,500 | 2/15 | 1/15 |
| 91 | 1,600 | 2/15 | 1/30 |
| | | *75 Cycle* | |
| 93 | 1,500 | Not applied | Died. |
| 94 | 1,500 | Immediately | 1/30 |
| 95 | 1,580 | 2/15 | 1/15 |
| 96 | 1,500 | 2/15 | 1/10 |
| 97 | 1,580 | 2/30 | Died. |

Having shown that block could be established in the cardinal centers of the brain by the passage of the 25-cycle alternating current, we became interested in determining whether these results would also be obtained for alternating currents of other frequencies. Through the kind co-operation of Professor Price of the Department of Electrical Engineering, University of Toronto, it was possible to obtain frequencies of 12.5, 60, and 75 cycles. It was obvious that, in order

be employed. This was provided as follows: The animal was anesthetized; electrodes were placed on the atloido-occipital membrane and in the nose, and the depth of anesthesia was allowed to lessen so that the eye reflex was obtained. A current of about 1,500 milliamperes was then applied for two seconds. The first animal tested at each frequency, was allowed to die. The second had immediate artificial respiration applied to it, while the remainder were allowed to wait for

varying intervals before the application of artificial respiration. This provided for all the conditions under which 25-cycle current had been applied. It can be seen by comparing Table 3 with Table 2 that there is no marked difference in the results obtained at varying frequencies.

TABLE 4.—RESULTS OF EXPERIMENTS ON RELAPSE

| RABBIT NO. | CURRENT APPLIED FOR 2 SECONDS *milliamp.* | INTERVAL BEFORE APPLICATION OF ARTIFICIAL RESPIRATION *min./sec.* | TIME OF RECOVERY *min./sec.* | ULTIMATE FATE |
|---|---|---|---|---|
| 47 | 1,400 | Immediately | 2/– | No relapse. |
| 48 | 1,620 | " | 2/53 | No relapse. |
| 49 | 1,480 | " | 1/50 | No relapse. |
| 51 | 1,500 | " | 2/10 | No relapse. |
| 53 | 1,620 | " | 1/10 | No relapse. |
| 54 | 1,650 | " | 1/30 | Died next morning. |
| 55 | 1,730 | " | 1/– | No relapse. |
| 56 | 1,590 | " | 1/40 | No relapse. |
| 58B | 1,600 | 2/– | 1/50 | No relapse. |
| 59 | 1,600 | 2/– | 1/5 | Died next morning. |

It appears to be the general impression among electrical workers that cases of electric shock suffer failures in breathing after spontaneous breathing has been reestablished. In order to determine whether such conditions obtain in laboratory animals, a number of experiments were performed in which the electrodes were applied under aseptic technic and the animals were observed from time to time during a period of forty-eight hours following the shock and resuscitation. Ten animals as listed in Table 4 were employed. Artificial respiration resulted in recovery in all animals. Two of them, however, were found dead on the morning following the shock, although both appeared quite normal when left the evening before, approximately four hours after the shock. The other eight animals appeared to be in no respect harmed by their experience, and they were eventually used for other purposes. It is impossible to tell what may have been the cause of death in these two animals and further experiments on this phase of the problem ought to be performed.

### A-C Block in the Spinal Cord

Since the foregoing experiments had demonstrated that a-c block of a temporary nature could be produced in the cardinal centers of the rabbit and the cat, it remained to be shown whether or not a similar block could be obtained in the spinal cord and in isolated nerve.

In the attempt to demonstrate block in the spinal cord many technical difficulties were encountered and these will be touched upon since it is essential that they be overcome for a successful result.

A cat was anesthetized and decerebrated according to Sherrington's tech-

nic. When hemorrhage had ceased and the animal had partially recovered from shock, the procedure as described by Sherrington for studying the crossed extension reflex was followed. Both femoral nerves were exposed below Poupart's ligament and all branches cut except that to the quadratus femoris. Both sciatic nerves were dissected free and one of them severed near its central portion. On the opposite side, the sciatic nerve was exposed as far as its division into anterior peroneal and posterior tibial branches, the anterior being left intact and the posterior ligatured and severed. The central ends of the sciatic and posterior tibial nerves were stimulated with a weak induced current from an inductorium.

In order that a graphic record of the response to stimulations of the cut nerves could be obtained, the animal was placed on its back with both legs suspended by passing a stout steel wire beneath the patellar tendon, and a thread was carried from each foot to the long end of a recording lever.

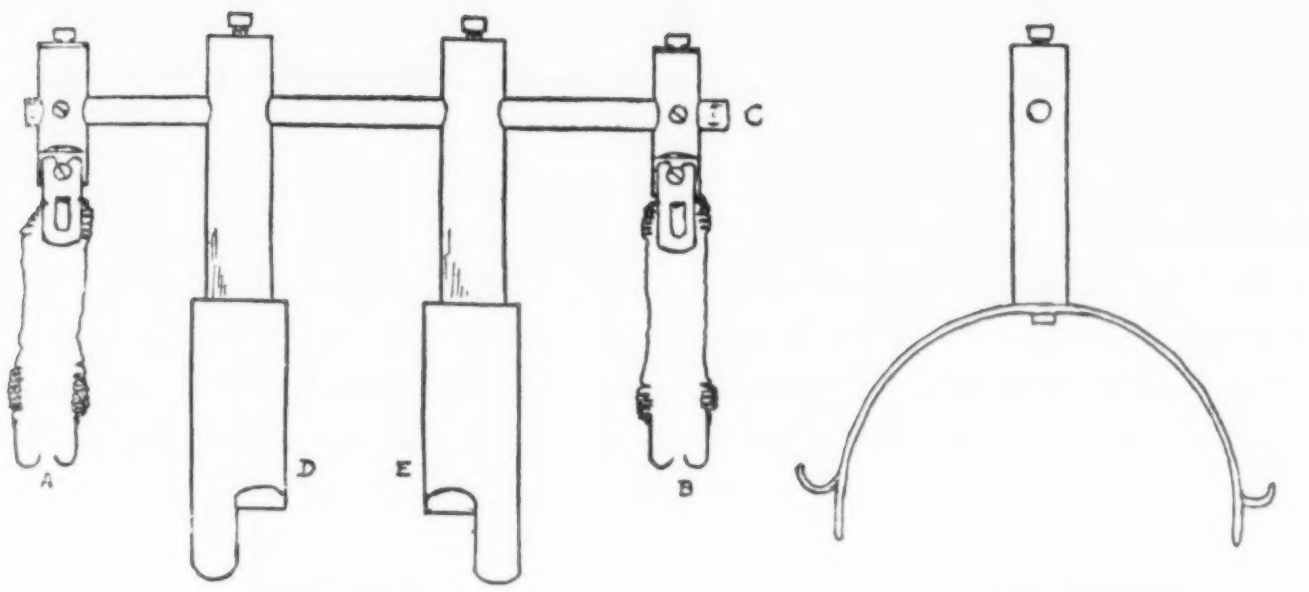
It was found that on stimulation of the central end of the cut sciatic nerve the crossed extension response (contralateral) was obtained, together with an ipsolateral relaxation. This reflex served to indicate the facility of spread of impulse across the cord. The flexion reflex was also observed in order to indicate the spread homolaterally. There was also found to occur an immediate and definite rise in the arterial blood pressure, some interference with respiration, and occasionally irregular contractions of the forelimbs. These phenomena can, of course, be accounted for by the irradiation of the exciting stimulus upward to higher centers, and their presence or absence indicates the condition of the long conducting pathways of the cord.

Some difficulty was experienced in finding a suitable method for the localized electrocution of the spinal cord.

The first method employed was to cut through the laminae of the second, third, and fourth dorsal vertebrae by means of a fine circular saw operated by a dental drill, and to place one electrode here and the other on the cauda equina after removing the sacral portions of the vertebrae. The use of the dental drill had to be abandoned largely because of danger of injury to the cord, and because of difficulty in its operation in the presence of muscle tissue and hemorrhage. In its place special curved rongeurs were used to remove the transverse processes and laminae of several vertebrae so that a length of from 3 to 4 cm. of the cord could be exposed. The upper electrodes used to secure contact with the cord consisted at this stage of a small hook of sheet platinum about $\frac{1}{8}$ inch across which was slipped under the cord; the lower electrode consisted of a blunt pointed length of $\frac{1}{8}$-inch copper wire inserted diagonally upward for about 1 inch between the sacrum and the lowest vertebrae, after the manner of a lumbar puncture. The decerebrate animal was supported on a wooden cradle so as to keep the electrodes free from the table, and graphic records of the reflex movements were made as before.

A series of seven experiments were carried out with the technic just described. Currents of from 40 to 200 milliamperes applied for two or three seconds were employed, the reflexes

FIGURE 1.




Lateral view Cross section

FIGURE 2.

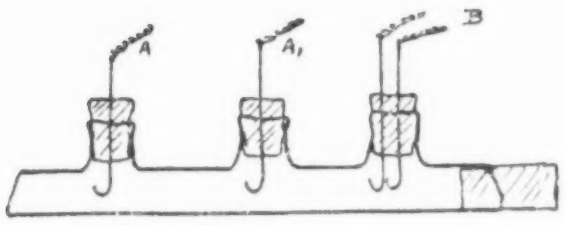



Figure 3.

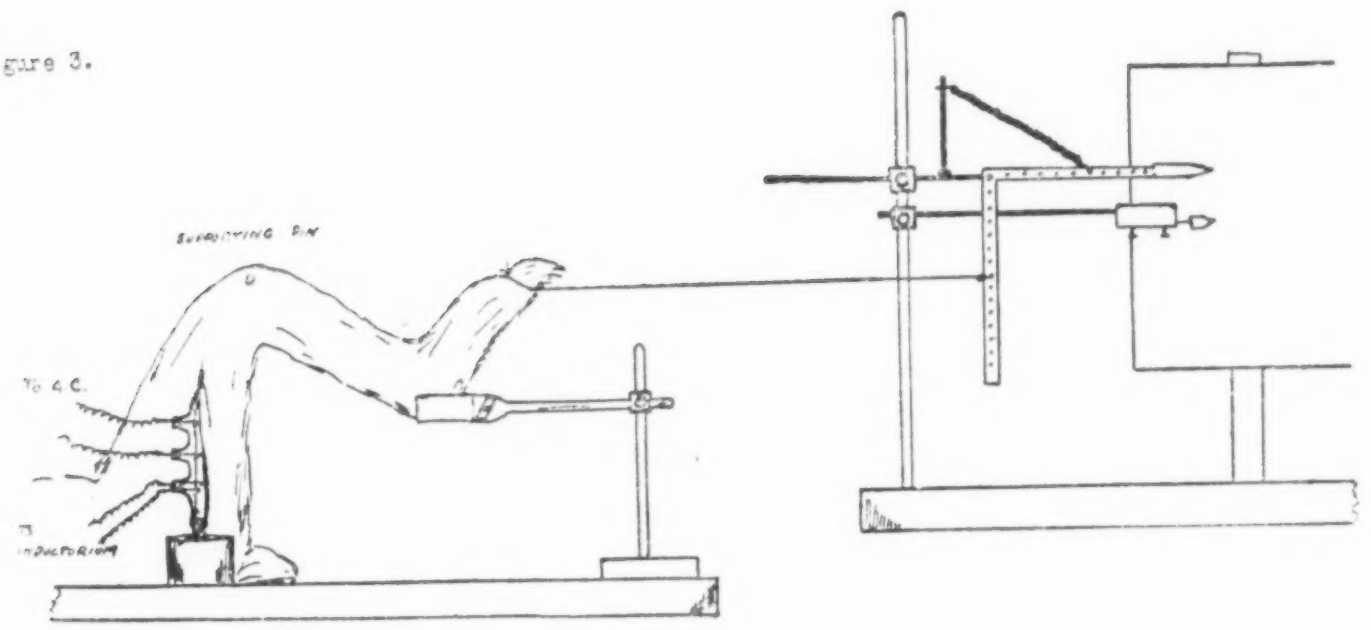



CHART 4

FIG. 1.—Special electrodes with saddle supports for electrocution of spinal cord.
A and B = double-hooked platinum electrodes. C = insulated bar. D and E = aluminium saddle supports.

FIG. 2.—Modified Sherrington electrodes for nerve.
A and $A_1$ = platinum electrodes. B = platinum electrodes for stimulating shocks from inductorium.

FIG. 3.—Mechanism for recording production of a-c block in the sciatic nerve of rabbit or cat.

being observed before and after the passage of the current. On one or two occasions the crossed extension reflex was absent immediately following the shock but failed to return, whereas the ipsolateral reflex was unaltered. On account of the poor condition of the animals as shown by a low body temperature and failing blood pressure, and since it was considered probable that adequate and constant contact with the lower end of the cord could not be made with the insertion of the wire electrode, these experiments were inconclusive and it was decided to repeat them under more favorable conditions. Thus, by means of external heat and frequent subcutaneous injections of glucose in saline, surgical shock was lessened and fairly constant body temperature and blood pressure were maintained. At the same time, two electrodes of the platinum hook type were placed under the spinal cord in two restricted areas, one at approximately the second dorsal and the other at the lower sacral region. After two or three experiments, it was found that the muscular contractions during, and immediately following, the passage of the alternating current frequently dislodged the electrodes; a more elaborate electrode was therefore designed (Chart 4, Fig. 1), which effectively remained *in situ*. It consisted of two aluminium saddles *D* and *E*, which were strapped about the animal's body with wide rubber bands, and two pairs of double-hooked platinum electrodes *A* and *B*, each of which was suspended on a fine coil of thin wire from an insulated bar *C*, which connected and was supported by the two saddles.

Several experiments were carried out at intermediary steps prior to the perfection of the illustrated electrode, but only the final series performed following its completion will be outlined.

The current employed in the previous experiments, *viz.*, from 40 to 400 milliamperes for three seconds, was found to be insufficient to affect the ipsolateral reflex, and accordingly currents of considerably higher amperage were used. Protocol 1 is typical of three experiments.

PROTOCOL 1

| | |
|---|---|
| Cat | Anesthetic. |
| 3:00 p.m. | Decerebrated; little hemorrhage; condition good; decerebrate rigidity pronounced. |
| 3:20 | Stimulation of central end of right sciatic; ipsolateral relaxation positive. Contralateral extension with a rise in blood pressure. |
| 3:30 | 750 milliamperes applied to cord for 2 seconds. |
| 3:31 | Stimulation of central end of right sciatic; negative. No effect on blood pressure. |
| 3:33 | Stimulation of central end of right sciatic; negative. No effect on blood pressure. |
| 3:34 | Stimulation of central end of right sciatic; negative. No effect on blood pressure. |
| 3:35 | Slight contralateral, marked ipsolateral reflexes. Blood pressure rose. |
| 3:39 | Definite contralateral, marked ipsolateral reflexes. Blood pressure rose. |
| | Duration of block, 5 minutes |

A similar result was obtained in another experiment using a current of 150 milliamperes for four seconds, the duration of block being one and a half minutes. In these experiments, move-

ments of the forelimbs which were evident on stimulation, prior to the passage of the current, were absent throughout the duration of the block, and returned coincident with the response from the hind limbs. These results were obtained on two occasions but graphs on a sufficiently reduced scale satisfactory for publication could not be secured.

*Discussion*

From these results it is apparent that, following the passage of an alternating current of suitable strength through a portion of the intact spinal cord of the decerebrate cat, a condition of block becomes established, as judged by the abolition of those reflexes which are dependent on the conductivity of that portion of the cord through which the current has passed. It had been hoped to use similar preparations for the purpose of determining to what extent the results would be altered by using currents of variable amperage, frequency, and so forth, but, on account of the extreme technical difficulties involved and the large number of experiments which had to be performed before reliable results, such as those exhibited in the protocol, could be obtained, it was decided to seek a more easily controlled preparation in the sciatic nerve.

A-C Block in Nerve

From the results of the foregoing experiments it might be expected that an a-c block analogous to that observed in the spinal cord could be produced in a mixed nerve. As an index of block, certain reflexes were employed in the former case, whereas in the latter the response of an attached muscle preparation to stimulation of its nerve was used.

The first experiments were carried out on the frog nerve-muscle preparation. The alternating current was applied to the nerve through a pair of fine platinum, hook shaped electrodes. The nerve was stimulated proximal to the area of block by means of ordinary electrodes attached to an inductorium delivering single break shocks, which were regulated so as to be just sufficient to cause a maximal contraction.

Tracings of contractions caused by three successive stimuli were made and then a current of low voltage passed for a period of two seconds through a length of nerve which was approximately 1 inch.

Stimulation with shocks of the same strength as those previously used was resumed every fifteen seconds until the response had returned to normal. A signal magnet was placed in series with the stimulating current. The results of such an experiment are shown in Chart 5. Here, break shocks produced a fairly constant contraction of the attached muscle, and, after normal tracings had been taken, an alternating current of 6 volts, the amperage of which could not be recorded, was passed through the nerve for two seconds. Stimulation of the proximal end of the nerve within five seconds showed no evidence of block, the contractions if anything being slightly increased. Next, a current of 7 volts was used, and the contractions following the first stimulus were diminished in height, the succeeding two being back to normal. Successively increasing voltages up to 12.5

were employed in a similar manner. From Chart 5 it will be seen that as the current is increased the extent and duration of the block, as judged by the diminution or absence of muscular contraction, become more pronounced.

Owing to scarcity of frogs, it was decided to employ the sciatic nerve in rabbits, using the flexion of the foot as an indication of the muscular response. In a series of such experiments the following points were investigated: (1) localization of block; (2) relationship between strength of current and degree and duration of block; (3) relationship between duration of current and degree and duration of block; and (4) recovery of nerve following passage of a strong current.

*Procedure*

A similar technic was employed in the investigation of the four problems, any particular variations being described under the individual headings.

A well-fed rabbit was anesthetized and maintained under a constant degree of light anesthesia. The sciatic nerve on one side was exposed throughout as great a length as possible, ligatured, and severed at its proximal end. The ends of the ligature were waxed, and threaded through the specially designed modification of Sherrington electrodes. (See Chart 4, Fig. 2.) The nerve was drawn carefully across the three contacts, $A$, $A_1$, and $B$, and secured in place by gentle traction on the ligature. The whole electrode was partially embedded in the muscular tissues of the thigh and secured in place by a suture and its lower end supported to prevent undue tension on the nerve. The animal was then secured on its back (see Chart 4, Fig. 3) and the leg fixed by means of a clamp at the first joint, and a stout steel pin passed through the patellar tendon. Graphic records of muscular response to stimulation of the nerve were obtained by connecting the distal phalanx of the prepared leg by means of a thread to one arm of a spring lever, the other arm of which recorded a tracing on a smoked drum.

The electrical equipment was arranged so that currents of variable voltages could be passed through the nerve by means of the terminals $A$ and $A_1$ (Chart 4, Fig. 2). Single break shocks from an inductorium could be sent in at $B$ at any given time.

An alternating current of sufficient strength to produce block was passed through the nerve, and stimuli were sent in at half-minute intervals until the muscular response returned to normal. The first indication of muscular contraction, as shown by the excursion of the lever, was taken as evidence of beginning restoration of conductivity, and the return of excursions to their previous height as an indication of complete recovery from the block.

*Localization of Block*

In several experiments this procedure was modified by the application of a second pair of electrodes so that the nerve could be stimulated both proximal and distal to the length of nerve through which the current was to be passed. In each instance, it was observed that prior to the passage of the electrocuting current both proximal and distal stimulation produced identical results; whereas immediately following the application

of a suitable alternating current distal stimulation was without result, while proximal stimulation remained unaltered. As the block was recovered from, distal stimulation again evoked its original response.

From these observations, it was concluded that the block was confined to the length of nerve through which the current passed, and that there was little or no spread of the area of block as in the phenomenon of electrotonus.

*Relationship between Strength of Current and Degree and Duration of Block*

It was found after several trials that, in order to produce a block of measurable duration, a current of about 20 volts and 2 milliamperes had to be applied for a period of two seconds. In order to investigate the relationship between the degree of block produced and the strength of current employed, a current of low voltage—from 12 to 20 volts—was passed through the nerve for two seconds. The voltage was then gradually increased. Whenever block occurred, ample time was allowed for complete recovery of the nerve before the current was again applied. The protocols of the experiments are here reproduced (Protocols 2 and 3), together with the graphic record of one of them (Chart 6).

From these results it will be seen that, provided the time element is constant, a definite threshold of current is required before block is induced. Once block is induced, its duration varies directly with the strength of the current. It was found in other experiments that a limit is reached beyond which recovery apparently does not occur. (Studies on the histologic changes in a nerve subject to a maximal shock are under investigation, and will be reported later.)

*Relationship between Duration of Current and Degree and Duration of Block*

The technic employed was similar to that described in the foregoing experiments.

A current was used which, when applied for two seconds, was known to produce a definite and pronounced degree of a-c block. Such a current, for example, in one experiment was 60 volts with 10 milliamperes and this was applied for varying fractions and multiples of a second. It was found that the current required varied with each individual experiment, owing possibly to such factors as the condition of the animal and particularly of the sciatic nerve; the efficiency of electrical contact and of connections; and the degree of anesthesia.

The protocols and graphic records of two typical experiments are here reproduced (Protocols 4 and 5; Charts 7 and 8). It will be seen that the duration of block bears a direct relationship to the length of passage of the current.

*Recovery of Nerve Following Passage of a Strong Current*

Since the duration of block apparently bears a direct relationship to the duration of the current, it became of interest to determine whether a current of sufficient strength might be applied for two seconds so as to produce such a degree of block that no recovery would occur. In order to allow of recovery taking place in the nerve,

PROTOCOL 2

May 14, 1928. Rabbit anesthetized and prepared as usual. Normal contractions elicited and recorded.

| TIME | CURRENT APPLIED FOR 2 SECONDS | | REMARKS |
|---|---|---|---|
| *p.m.* | *volts* | *milliamp.* | |
| 2:28 | 12 | .... | Contractions normal. No block. |
| 2:30 | 12 | .... | No block. |
| 2:35 | 20 | .... | No block. |
| 2:40 | 25 | 2.0 | No block. |
| 2:50 | 50 | 8.0 | Definite block lasting 10 sec., with complete recovery. |
| 2:55 | 10 | .... | No block. |
| 2:58 | 20 | 2.0 | Slight block. |
| 3:01 | 30 | 5.5 | Block. |
| 3:07 | 40 | 6.5 | Block. |
| 3:14 | 45 | 8.5 | Block. |
| 3:38 | 60 | 10.0 | Block. |
| 3:44–3:50 | .. | .... | Drum stopped for 6 min. |
| 3:55 | .. | .... | Gradual but not complete recovery. Condition of animal only fair. |

PROTOCOL 3[1]

May 10, 1928. Rabbit anesthetized and prepared as usual.

| TIME | CURRENT APPLIED FOR 2 SECONDS | | REMARKS |
|---|---|---|---|
| *p.m.* | *volts* | *milliamp.* | |
| 3:18 | Normal contractions elicited and recorded. | | |
| 3:20 | 20.0 | .. | No block. |
| 3:22 | 20.0 | .. | No block. |
| 3:24 | 30.2 | 5.5 | Complete block, 30 sec. |
| 3:30 | 30.2 | 5.5 | Complete block, 45 sec.; partial, 60 sec. |
| 3:32 | 39.8 | 6.5 | Complete block, 75 sec.; partial, 75 sec. |
| 3:36 | 49.0 | 9.0 | Complete block, 80 sec.; partial, 85 sec. |

[1] For graphic record of experiment, see Chart 6.

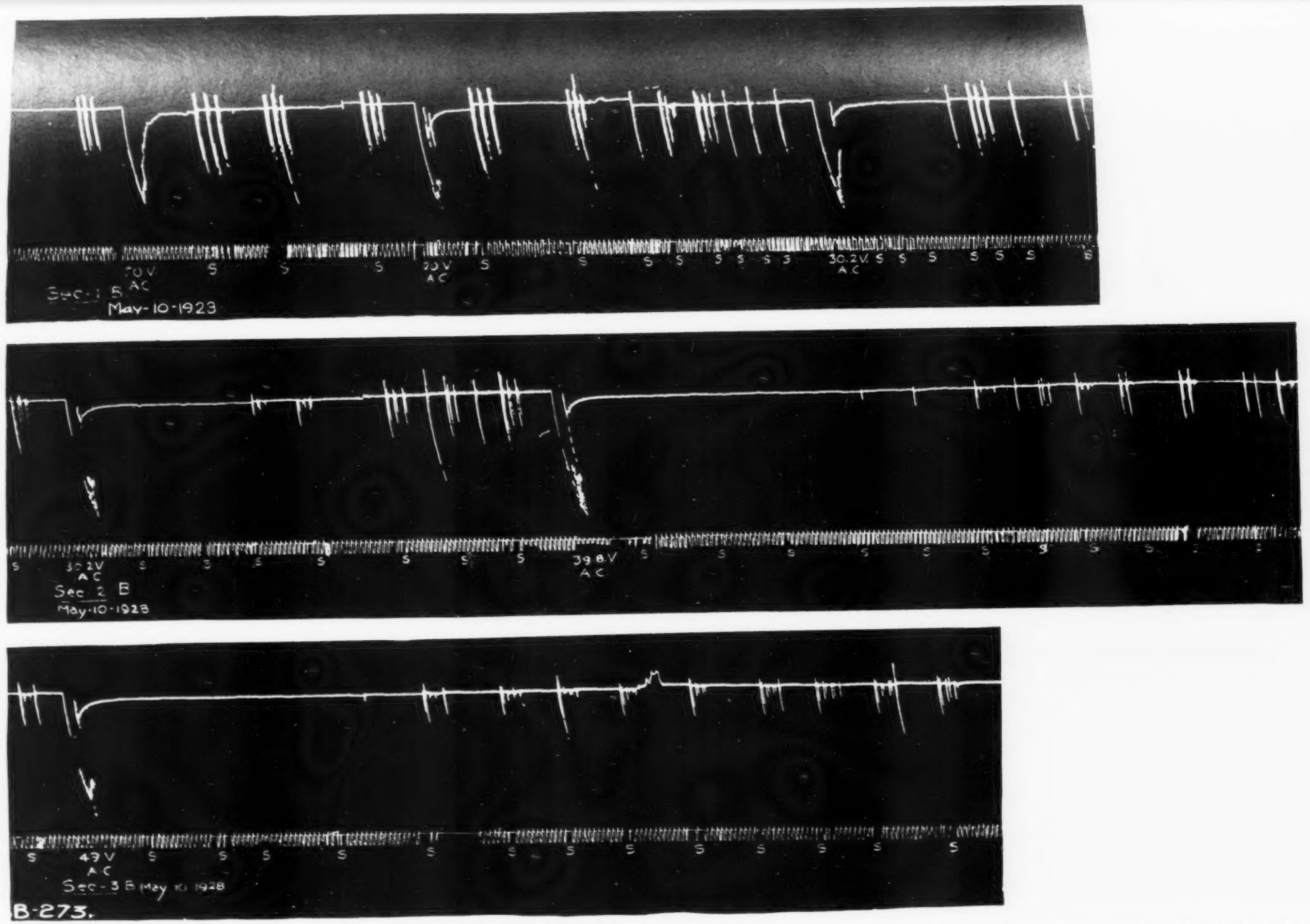



CHART 6.—May 10, 1928. Showing that block to stimulation by break faradic shocks becomes established in the sciatic nerve of the rabbit at a certain voltage of the alternating current and progressively deepens as the voltage is increased. See Protocol 3.

S = application of break shocks.

## PROTOCOL 4[1]

May 17, 1928. Rabbit prepared as usual. Normal contractions elicited.

| TIME *p.m.* | CURRENT APPLIED *volts* | DURATION OF CURRENT *sec.* | REMARKS |
|---|---|---|---|
| 3:44:25 | 60 | $\frac{1}{2}$ | Block. |
| 3:45:45 | .. | .. | Slight response. |
| 3:46:25 | .. | .. | Complete recovery in 2 min. |
| 3:47:0 | 60 | $\frac{3}{4}$ | Block. |
| 3:48:45 | .. | .. | Slight response. |
| 3:49:25 | .. | .. | Complete recovery in 2 min., 25 sec. |
| 3:50:05 | 60 | 1 | Block. |
| 3:52:40 | .. | .. | Slight response. |
| 3:53:40 | .. | .. | Partial recovery. |
| 3:54:0 | .. | .. | Complete recovery in 3 min., 55 sec. |
| 3:55:40 | 60 | $1\frac{1}{2}$ | Block. |
| 3:58:30 | .. | .. | Slight response. |
| 4:02:0 | .. | .. | Partial recovery. |
| 4:04:40 | .. | .. | Complete recovery in 9 min. |
| 4:07:20 | 60 | 2 | Block. |
| 4:09:50 | .. | .. | Slight response. |
| 4:17:40 | .. | .. | Complete recovery in 10 min., 20 sec. |

[1] For graphic record of experiment, see Chart 7.

## PROTOCOL 5[1]

May 18, 1928. Rabbit prepared as usual. Normal contractions elicited.

| TIME *p.m.* | CURRENT APPLIED *volts* | DURATION OF CURRENT *sec.* | REMARKS |
|---|---|---|---|
| 2:54:10 | 60 | $\frac{1}{3}$ | Temporary block. |
| 2:55:0 | .. | .. | Complete recovery in 50 sec. |
| 2:55:45 | 60 | $\frac{1}{2}$ | Block. |
| 2:56:50 | .. | .. | Slight response. |
| 2:57:10 | .. | .. | Complete recovery in 85 sec. |
| 2:58:0 | 60 | 1 | Block. |
| 2:59:40 | .. | .. | Response. |
| 3:00:40 | .. | .. | Complete recovery in 160 sec. |
| 3:01:50 | 90[2] | .. | No recovery from block noted in 15 min. |

[1] For graphic record of experiment, see Chart 8.

[2] Given in error.

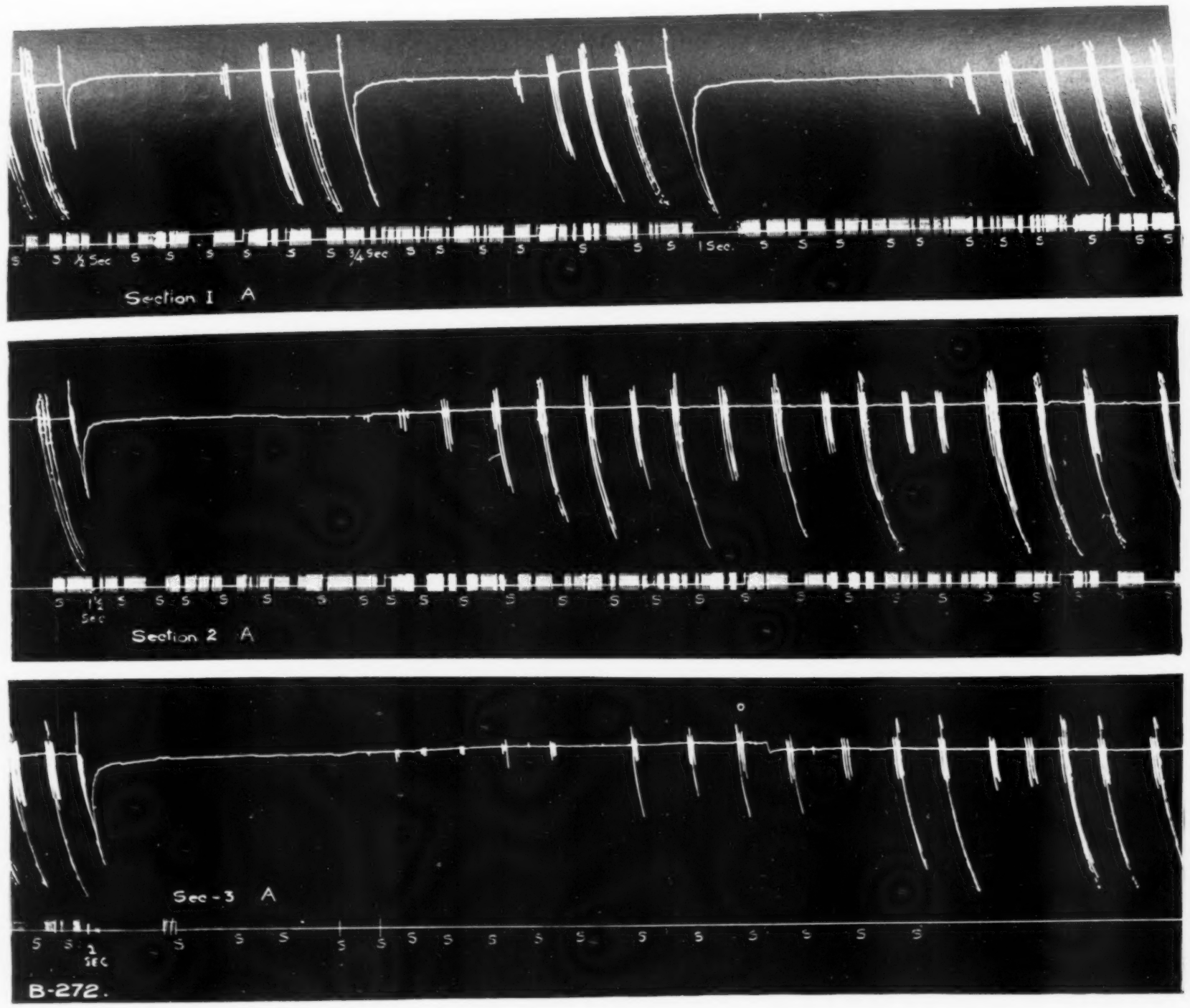



CHART 7.—Showing the effects of increasing the duration of application of the alternating current on the intensity of block in the sciatic nerve of the rabbit. See Protocol 4.

PROTOCOL 6[1]
June 19, 1928

| TIME | CURRENT APPLIED FOR 2 SECONDS | | REMARKS |
|---|---|---|---|
| *p.m.* | *volts* | *milliamp.* | |
| 2:00:0 | Animal prepared as in previous experiments. | | |
| 2:01:0 | Stimulus; normal contraction recorded. | | |
| 2:03:30 | 37 | .. | Block. |
| 2:04:0 | ... | .. | First response. |
| 2:09:30 | ... | .. | Normal response. |
| 2:21:0 | 115 | 13 | Block. |
| 2:29:30 | ... | .. | Slight response. |
| 2:40:0 | ... | .. | Normal response after 19 min. |
| 2:44:0 | 150 | 20 | Block. |
| 3:14:0 | ... | .. | No response in 30 min. Animal in good condition. Nerve removed for pathologic examination. |

[1] For graphic record of experiment, see Chart 9.

it was obvious that the animal should be maintained in good condition and that no gross damage, *e.g.*, charring, should have been produced by the current. Protocol 6 illustrates such an experiment.

In this experiment, following the passage of 115 volts with 13 milliamperes for two seconds, complete block was induced for eight and one-half minutes, the nerve returning to a normal state in nineteen minutes. Following the use of 150 volts with 20 milliamperes for two seconds, after thirty minutes there was still no indication of returning conductivity, the condition of the animal remaining excellent.

We may, therefore, presume that following the passage of a relatively strong current for two seconds through nerve a degree of block is established, from which the nerve does not recover in a reasonably long period of time.

## Conclusion

1. The passage of an alternating current through the base of the brain in rabbits (and cats) sets up a condition of block (a-c block) during which there is failure of respiration, and the usual responses through the cardiovascular and conjunctival reflex centers fail to be elicited. This confirms the conclusion previously drawn by one of us (R. W. I. U.).

2. Unless the alternating current has been of such intensity as to cause charring of the nerve structures, the block is gradually recovered from, provided the animal has meanwhile been subjected to artificial respiration. Breathing and the various reflexes return about the same time.

3. The alternating current causes a similar condition of temporary block in the centers of the lower portion of the spinal cord in decerebrate cats, as

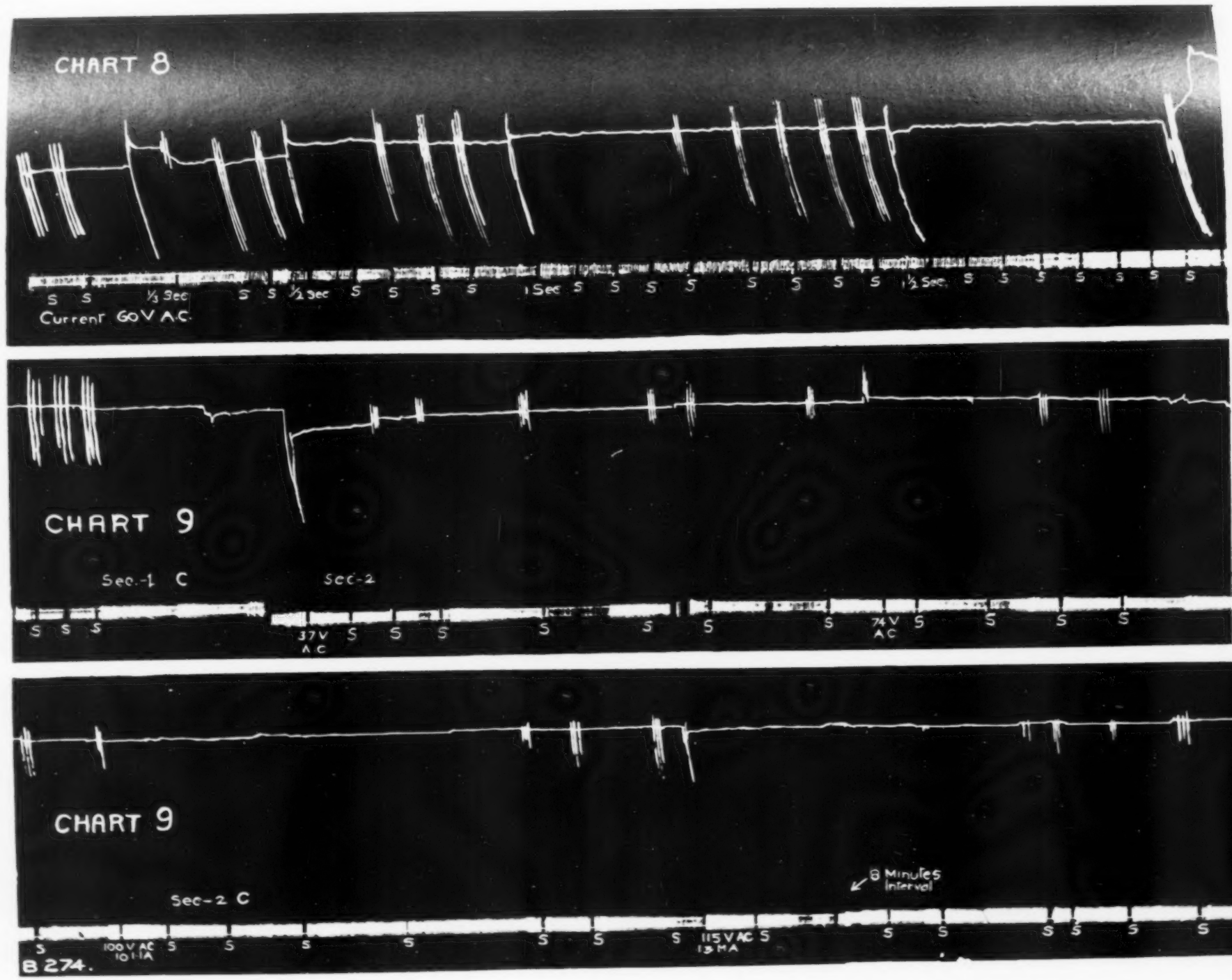


CHART 8
S S ⅓ Sec S S ½ Sec S S S S 1 Sec S S S S S S S S ½ Sec. S S S S S S S
Current 60 V A.C.
CHART 9
Sec-1 C
Sec-2
S S S
37V A.C
S S S S S S S
74V A.C
S S S S
CHART 9
Sec-2 C
8 Minutes Interval
S 100 V AC 10 1 A S S S S S S S 115 V AC 13 MA S S S S S S S S S
B 274.

CHART 8.—Showing the effects of increasing the duration of application of the alternating current on the intensity of block in the sciatic nerve of the rabbit. See Protocol 5.

CHART 9.—Showing the effects of increasing the voltage of the alternating current on the intensity of block in the sciatic nerve of the rabbit. See Protocol 6.

demonstrated by the behavior of the flexion and crossed extension reflexes.

4. The conducting pathways in the spinal cord are also temporarily blocked by the alternating current as demonstrated by the disappearance of reflex change in blood pressure and of the free limb movements.

5. A-c block may also be demonstrated in nerve and this has been done most successfully in using the sciatic nerve of the rabbit. By means of this preparation, the relationship between the strength and duration of the alternating current and the intensity of the block has been worked out. It is to be noted that following the passage of a relatively strong current through nerve a degree of block is established from which recovery does not occur within a reasonably long period of time.

6. The addition of carbon dioxide to the air used for artificial respiration, or the use of oxygen instead of air for this purpose, does not hasten the return of normal breathing in electrocuted rabbits. Injection of adrenaline is also of no advantage.

The authors wish to express their thanks to Prof. J. J. R. Macleod for his continued interest throughout the progress of this work; and to Mr. Wills Maclachlan, Consulting Engineer, and his associates on the Hydro-Electric Power Commission of Ontario for the assistance and facilities they so kindly provided.

To Mr. F. L. Harrison, Electrical Assistant, High Tension Laboratory of the Hydro-Electric Power Commission of Ontario, a special debt of gratitude is due for his skill and resourcefulness in fulfilling the somewhat exacting electrical requirements. It is through his co-operation that such results as have been obtained were made possible, and the authors take this opportunity of expressing their appreciation.

## BOOK REVIEWS

First Aid and Ambulance for Factories and Workshops. Home Office, Welfare Pamphlet No. 4. Second edition. Pp. 24. London: H. M. Stationery Office, 1929.

This excellent memorandum deserves a second edition. It is hard to overestimate the good it has done. Iodine and sterilized dressings with *no washing* is the approved line of treatment. The necessary equipment is described and illustrated, and the method of use is set out. Ambulance rooms and conveyances are dealt with; and the way to organize a first aid personnel. The need for keeping and studying accident records is stated. The plans and plates are clear and useful. The law relating to the subject in Welfare Orders and in the Workmen's Compensation Act, 1923, is stated. The whole pamphlet is a model in value and condensation. —*E. L. Collis.*

Staubgefährdung und Staubschädigungen der Metallschleifer insbesondere der des bergischen Landes. By Landesgewerbearzt Dr. *Teleky*, Medizinalrat Dr. *Lochtkemper*, Dr. *Erika Rosenthal-Deussen* und Gewerberat *Derdack*. Paper. Pp. 205 with illustrations and bibliography. Arbeit u. Gsndht., no. 9. Berlin: Reimar Hobbing, 1928.

The work of metal grinders in Solingen and the injury to health consequent upon their exposure to dust is the subject of this work. A large series of dust count experiments was made using the Owens dust counter, which Dr. Teleky prefers to the Kotzé konimeter as being more accurate, although he considers that the ideal dust counter is still to be made.[1] He finds, as does Dr. Middleton, that wet sandstone grinding produced the greatest amount of dust, and the most dangerous (quartz); manufactured grindstones produced less dust and that of a less dangerous character (chiefly iron) and more easily removable by dust exhaust plant.

He strongly advocates the extension of the use of manufactured stones as in England. There is need of improvement in dust exhaust apparatus and it is a subject which should receive more attention from technical experts.

Dust counts similarly obtained from the Sheffield workshops by Dr. Middleton were much higher than those in Solingen. Dr. Teleky gives as reasons for this: (*a*) the threefold arrangement of grinders in Sheffield; (*b*) the Sheffield grindstones mostly turn away from instead of toward the worker; and (*c*) the usually greater number of grindstones per room in Sheffield.

Careful clinical and X-ray examinations were made by Dr. Lochtkemper of 100 metal grinders. In common with other observers he

[1] The most recent konimeter made is a Zeiss. It consists of a revolving glass disk $2\frac{1}{2}$ inches in diameter divided into 30 equal spaces which are numbered. To each space the amount of dust in either a 5-c.c. or a 2.5-c.c. sample of air can be made to adhere. Attached to the konimeter is a microscope which has a magnification of 200. It is delightfully compact and easy to manipulate and should be especially useful in mines.—S. W. F.

notes that the clinical findings showed that a characteristic and diagnosable disease—pneumonokoniosis—is produced by dust inhalation, but that specific symptoms are nonexistent. Only a number of nonspecific symptoms (*e.g.*, cough, dyspnea, liability to catch cold (even in summer), etc.) taken in conjunction with the clinical and occupational history together with an X-ray examination can establish the diagnosis. Consequently the diagnosis should be in the hands of skilled chest clinicians, one for each large district, equipped with and expert in the use of up-to-date X-ray apparatus—an opinion of interest to those who have to consider the medical arrangements of an extended silicosis scheme.

Dr. Lochtkemper also recommends periodic examination every three years, by such a physician, of all sandstone grinders, and, at shorter periods, of workers already affected. He considers that as technical measures are not yet sufficiently efficient to prevent dust inhalation, diseases due to it should be placed on the same footing as accidents with regard to compensation.

Dr. Lochtkemper classifies pneumonokoniosis into three stages according to the X-ray findings and he repeatedly stresses the value of X-rays for differential diagnosis.

In the first stage he places cases showing enlarged hilus glands and more or less increased fibrosis in the peribronchial, perivascular, and interstitial lymph channels, indicated by the more distinct outlining of the vessels.

The second stage embraces advancing cases with much increased induration; solitary infiltrated nodules and a reticular or honeycomb-like (*wabenartig*) structure are in evidence here.

To the third stage belong cases in which both lung fields are strewn over with isolated, sometimes confluent, nodules giving the "snowstorm" appearance.

TABLE 1.—STAGES OF PNEUMONOKONIOSIS

| | NO SIGNS OF DUST | STAGES OF PNEUMONOKONIOSIS | | |
|---|---|---|---|---|
| | | I | II | III |
| Polishers | 4 | 7 | .. | .. |
| Fine glazers | .. | 9 | .. | .. |
| Coarse glazers | 4 | 8 | 2 | 1[1] |
| Manufactured stone | 2 | 10 | 2 | .. |
| Dry sandstone | 4 | 1 | 8 | 2 |
| Wet sandstone | .. | 19 | 6 | 11 |

[1] This man worked twenty-three years in the same room with wet sandstone grinders.

Table 1 (a reproduction of Table 31) shows to what extent pneumonokoniosis was found in the 100 grinders examined; about thirty interesting reproductions of the films taken illustrate the text.

This work as a whole, although presenting no strikingly new features, succeeds in conveying to the reader a short yet complete account, not only of metal grinding in Solingen, but also of present day knowledge of lung disease due to the inhalation of dust, the methods of investigation, and means of prevention.—*E. M. Fisher* and *S. W. Fisher*.